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ABSTRACT

The research and development efforts performed by principal investigators under sponsorship of the Office of Naval Research Cognitive and Neural Sciences Division during 1988 are documented. The title, name and affiliation of the principal investigator, project code, contract number, current end date, technical objective, approach, and progress of each program are listed. Under the heading "Cognitive Science" are four clusters: (1) cognitive architectures and abilities; (2) knowledge, skill, and expertise; (3) learning and instruction; and (4) measurement and psychometric theory. Research in this area is aimed at providing a theoretical understanding of the human learner and performer in the domain of complex cognitive skills. Research in the "Perceptual Science" program is grouped into clusters of: (1) vision; (2) attention; (3) audition; (4) haptics and sensory guided motor control; (5) decision making; and (6) human factors technology. Biological intelligence programs foster research to elucidate the organization, structure, and operational algorithms of the neural systems. Clusters under the heading "Biological Intelligence" include: (1) computation in large neural networks; (2) chemical modulators of information processing; (3) neural processing of sensory information; (4) local neural circuit interactions; (5) marine mammals; and (6) behavioral immunology. There is also an interdisciplinary program of exploratory development called the "Manpower, Personnel, and Training Research and Development Program." The individual programs under each cluster are work units either active or completed in 1988. (SLD)

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Cognitive And Neural Sciences Division

1988 Programs

OFFICE OF NAVAL RESEARCH

Arlington, VA 22217-5000

August 1988

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FOREWORD

This booklet describes research carried out under sponsorship of the Cognitive and Neural Sciences Division of the Office of Naval Research (ONR) during fiscal year 1988. The Division's research is organized in three programs: Cognitive Science, Perceptual Science and Biological Intelligence. Each program is described by an overview which is followed by thematic clusters of related efforts. Each cluster is described by individual projects, work units, which were either active or completed during 1988.

This is one of several means by which we communicate and coordinate our efforts with other members of the research-sponsoring and research-performing communities. We encourage your comments about any feature of this booklet or about the programs themselves. If you wish further information, please do not hesitate to contact members of the staff listed in the Introduction. We welcome your interest in our programs and hope that you will continue to keep us informed of related research efforts.

W. S. VAUGHAN, JR.

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INTRODUCTION

Cognitive and Neural Sciences Division programs are carried out under contracts and grants awarded on the basis of proposals received in response to a Broad Agency Announcement in the Commerce Business Daily. They are evaluated on the scientific merit of the proposed research, the facilities available for its conduct, the competence of the principal investigator, and relevance to Navy needs. The elements that shape our research program are scientific gaps and opportunities, and operational needs identified in Navy planning documents. Our overall aim is to support quality science for the good of the Navy and the nation.

Cognitive and Neural Sciences programs develop fundamental knowledge about human capabilities and performance characteristics which guide Navy and Marine Corps efforts to improve personnel assessments for selection and classification, training, equipment and system designs for human operation and maintenance. One goal is to provide scientific underpinning for more accurate prediction and enhancement of human performance in training and operational environments. A second goal is to understand the neurobiological constraints and computational capabilities of neural information processing systems for future device implementation. The Division has core programs in cognitive, perceptual and neural sciences which seek to understand human behavior at successively deeper levels of analysis. In addition, several Accelerated Research Initiatives (ARI) are underway which complement and extend research topics of interest to the core programs.

Most of the programs are basic in nature, with a selected augmentation of exploratory development effort. This mix of basic and applied research is developed and managed by the Division staff with the able assistance of other ONR scientists and with helpful guidance and advice from representatives of various Navy and Marine Corps activities. The programs seek to involve innovative civilian scientists in areas of research relevant to Navy and Marine Corps interests, and by so doing provide new perspectives, new insights, and new approaches to naval manpower, personnel, training, equipment and system design problems. This arrangement provides channels for information to flow back and forth between the civilian research community and the naval community, each keeping the other abreast of new developments. The emphasis is on the creation and exploitation of a cumulative scientific knowledge base upon which new technologies can be developed to improve effectiveness of Navy and Marine Corps men and women.

Continuous efforts are made to coordinate the Division's research program with other ONR contractors, with in-house Navy laboratories, and with the research sponsored by other services and other agencies. We work closely with research managers at the Navy Personnel Research and Development Center (NPRDC), the Chief of Naval Education and Training (CNET), the Naval Medical Research and Development Command (NMRDC), the Marine Corps, and the Naval Systems Commands (NSC) and their laboratories and centers to promote the diffusion, extension, and eventual utilization of the knowledge obtained through the ONR contract research programs.

The Cognitive and Neural Sciences Division is part of the Life Sciences Directorate, which also includes the Biological Sciences Division. Dr. Steven F. Zornetzer is Director of the Life Sciences Directorate, and Commander Charles J. Schlagel is the Deputy Director for Life Sciences.

DIVISION STAFF

The members of the staff of the Cognitive and Neural Sciences Division are listed below:

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COGNITIVE SCIENCE
(CLUSTERS 1 - 4)

The Cognitive Science research program of the Office of Naval Research aims to provide a theoretical understanding of the human learner and performer in the domain of complex cognitive skills. This general goal unfolds into several interrelated more specific objectives. First, to provide a theory of the fundamental characteristics of the learner and performer as an information processing system, including a theory of the basis of individual differences in cognitive abilities. Second, to provide a theory of the nature of acquired knowledge and skill involved in performing complex problem-solving and decision-making tasks. Third, to provide a cognitive learning theory that can account for the way in which such complex, structured bodies of knowledge and skill are acquired. Fourth, to provide a precise theory of instruction, founded on cognitive theory, to be used to guide effective education and training of complex cognitive skills such as those involved in performing Naval duties. Finally, this research program aims to provide theoretical foundations for personnel testing and assessment. Research in Cognitive Science is expected to lead to the design of efficient instructional systems across a range of content domains of interest to Navy and Marine Corps training programs, to the development of efficient and accurate computer-based personnel assessment systems, and to the design of expert advisory systems compatible with human intellectual characteristics.

1. The Human Learner: Cognitive Architectures and Abilities

Research aimed at discovering and characterizing the stable features of the human learner emphasizes later stages of information processing -- cognition rather than perception. This cluster of projects is developing theories for the functional architecture of cognition, including subtheories for memory and elemental cognitive processing operations. Results of research in this cluster will provide sound theoretical bases for personnel testing and selection, and for the individualization of instructional treatments based on accurate diagnosis of cognitive capacities.

2. Knowledge, Skill and Expertise

Research on knowledge and expertise aims at formal theories of complex human skill. The program emphasizes the expression of theories on the formal languages provided by mathematics and computer science and includes empirical tests of developed models. Projects target a wide range of complex skills, emphasizing problem-solving and

decision-making, so that a general theory can evolve. Research results are intended to provide a general model for skill analysis that can be used to design appropriate training or expert advisory systems.

3. Learning and Instruction

Research on Learning and Instruction aims to produce a knowledge-rich theory of learning that integrates results of work in the prior clusters and develops a coordinated instructional theory that explains how to deliberately produce change -- learning -- in desired directions. Under the Knowledge Acquisition ARI, there is currently a major emphasis on AI-based models of complex human learning. Artificially intelligent, computer-assisted instructional systems as well as more conventional instructional settings are the application areas for the program. Projects are supported which involve either fundamental advances in AI bases for intelligent tutoring or the use of intelligent tutoring systems as a laboratory for investigation into general issues of learning and instruction.

4. Measurement and Psychometric Theory

Research on psychological measurement aims to develop psychometric theory and method to support improved measurement of the knowledge, skills and capabilities of individual Navy and Marine Corps men and women. Work involves theoretical development of the psychological and measurement foundations, mathematical and numerical development of modelling techniques, and experimental and simulation studies to assess adequacy of the approach. As in other clusters, the emphasis is on modelling performance of complex tasks which engage higher-order cognitive structures and processes.

PERCEPTUAL SCIENCE
(CLUSTERS 5 - 10)

Research in the Perceptual Science Program emphasizes issues of perceptual primitives, their representations and transformations in the domains of vision, audition, touch and manipulation, multimodal integration and the control of motor function. Research results are anticipated to transition to Navy and Marine Corps systems in the form of filtering and processing algorithms that enable enhanced performance in detection, classification and control tasks.

5. Vision

Vision is viewed as a computational process and projects in this cluster emphasize interdisciplinary approaches. Mathematical models are constrained by neurophysiological evidence and tested by psychophysical experiments. Focus is on modeling early, intermediate, and late-visual processes that construct and recognize visual forms and integrate these forms into complex visual representations.

6. Attention

A second thrust inquires into the nature of neural mechanisms of control. In their more evolved forms, brains contain special modulatory mechanisms that enable them to adjust quickly and adaptively to momentary fluctuations in environmental demand. These are the neural control mechanisms underlying attention and arousal. Interest within this cluster is on empirical research in human performance, neuroanatomy, neurophysiology, and neuropsychology aimed at investigation of the control structures and circuitries underlying attention, and the neurochemical modulators governing attentional processing.

7. Audition

In audition, research projects examine the processing of steady state, transient and reflected acoustic signals, model the concurrent processing of complex sound properties and interactions, and develop general theories of audition that predict and enhance human performance in auditory pattern detection and classification. Current emphasis is on understanding and modeling the classification processes of human listeners, augmented by neurophysiological evidence from other biological species with interesting auditory capabilities and the signal-processing capabilities of artificial neural nets. The major operational problem context for this program is sonar signal processing in anti-submarine warfare.

8. Haptics and Sensory Guided Motor Control

Sensory-guided motor control is a new area of interest in Perceptual Science. Emphasis is on experimental and theoretical studies of the fundamental issues of coordinated motor function, including the computational bases of force control, and the timing and sequencing of action. Special emphasis is given to work investigating the processes through which sensory information functions as an adaptive guide to coordinated action. Interdisciplinary research is encouraged in psychology, neuroscience, and computer science to achieve an understanding of sensory-guided motor control that will contribute toward enhancement of action adaptability within robotic systems.

The processing of tactile and kinesthetic information in object recognition is a related area of interest in this cluster. Priority research issues include the identification of perceptual primitives, neural network models for tactile processing in somatosensory centers, and perceptual mechanisms that mediate inferential judgments about object properties, classifications and function. Interdisciplinary research is encouraged in psychology, neurophysiology and computer science with the goal of understanding the haptic system in order to provide future robotic devices with intelligent hands.

9. Decision Making

This cluster includes research on both individual and team decision making. The research on team decision is a special multidisciplinary project involving psychological, mathematical, computer science and communications approaches to basic issues in multi-person, cooperative decision making. The project is intended to provide scientific underpinnings in the form of theories, models, methods and functional relationships among key variables which define decision making in geographically dispersed, decentralized command/control systems characteristic of Navy battle groups. Initial research topics of concern include strategies for decomposing complex problems that lead to effective organizational architectures, strategies for aggregating multi-person judgments, estimates and plans leading to effective consensus, and strategies for maintaining data base concurrency in dynamic, multi-operator environments. The program emphasizes measures of effectiveness for distributed decision systems with special attention to the issues of reconfiguration and reconstitution after loss or degradation of one or more decision centers. Scientific Officers from ONR Code 1111SP, 1114SE, 1142PS and 1211 oversee scientific progress; joint funding is provided by the aforementioned ONR Codes. The Director of the Cognitive and Neural Sciences Division has overall responsibility for the management of this cluster of research.

10. Human Factors Technology

The work described in this cluster constitutes an Exploratory Development project which is designed to extend the basic research program in Perceptual Science toward applications in naval systems. Currently the project consists of applied research in four topic areas: decision making in command and control systems; human factors design for maintainability; human-computer dialogue; and supervisory control. In the command and control area, the various work units are investigating information processing and decision performance in naval mission planning, airborne ASW, and submarine combat control. In the maintenance area, efforts are directed toward the development of analytical techniques and models of technician performance which can be used to predict the maintainability of equipments as a consequence of design characteristics. The work on supervisory control is exploring the application of new interactive control concepts to underwater vehicles and remote manipulators.

BIOLOGICAL INTELLIGENCE
(CLUSTERS 11 - 16)

Biological Intelligence programs foster research to elucidate the organization, structural bases, and operational algorithms characterizing information processing networks within neural systems. The goal is to uncover neural architectures and algorithms that can profitably be emulated technologically to yield artificial information processing capabilities of kinds now unique to biological systems. These neural architectures may be derived from either sensory-, motoric- or cognitively-related structures. Overall, the program of research seeks to uncover the organizational principles and operational rules exploited within neural networks to compute intelligent functions, and to emulate these network characteristics within electronic information processing systems.

11. Computation in Large Neural Networks

This research examines the global dynamics of biological neural networks composed of large numbers of neurons. The goal of this research is a formal description and simulation of the biological computations underlying information processing, learning and cognition in order to design electronic information processing systems with these network characteristics.

12. Chemical Modulators of Information Processing

This cluster of research explores the mechanisms by which neurochemical modulators and neurotransmitters enable neural plasticity, modify information processing, and alter network dynamics.

13. Neural Processing of Sensory Information

This research is concerned with the functional organization of sensory neocortex, the computations performed in sensory cortical networks, and the adaptive plasticity of these networks evident at the level of the neuronal receptive fields.

14. Local Neural Circuit Interaction

This research advances our understanding of the elements of neural circuits, the individual neurons, by investigating small ensembles of neurons. This research encompasses investigations of the integrative capacities of the dendritic branching structure of neurons, the rules which govern modification of synaptic strength, and the role of membrane electrical properties in information processing and neural plasticity.

membrane electrical properties in information processing and neural plasticity.

15. Marine Mammals

An Accelerated Research Initiative, Marine Mammals, investigates a variety of marine mammal capabilities such as detection, localization, recognition, spatial orientation, and communication. The general purpose is to discover underlying principles governing these skill expressions for potential use in both natural and artificial systems.

16. Behavioral Immunology

This program is an Accelerated Research Initiative jointly funded by the Biological Sciences and the Cognitive and Neural Sciences Divisions. The program aims at understanding the processes, both biological and psychological, by which life stresses come to influence the functions of the immune system and susceptibility to illness. The projects described are those currently managed by this Division.

MANPOWER, PERSONNEL AND TRAINING RESEARCH AND DEVELOPMENT PROGRAM

This is an interdisciplinary program of exploratory development managed by Dr. Stanley Collyer in the OCNR Office of Naval Technology. Scientific Officers for these projects are located in the Cognitive and Neural Sciences Division and in the Mathematics Division of the Office of Naval Research. This brochure includes descriptions only for those contracts managed by a Scientific Officer in the Cognitive and Neural Sciences Division.

This program is closely coupled with the operating arms of the Navy and Marine Corps through the mechanism of a planning committee, whose members include ONR Scientific Officers, the Naval Civilian Personnel Command, the Naval Military Personnel Command, the Navy Recruiting Command, the Navy Personnel Research and Development Center, several directorates in the Office of the Chief of Naval Operations, and the Navy Secretariat.

COGNITIVE SCIENCE

CLUSTER 1

THE HUMAN LEARNER: COGNITIVE ARCHITECTURES AND ABILITIES

TITLE: Mental representation of spatial transformations

PI: Martha J. Farah
Carnegie Mellon University
Department of Psychology
(412) 578-3790

R&T PROJECT CODE: 400x020 CONTRACT NO: N0001486K0094

CURRENT END DATE: 31 DEC 1988

Technical Objective: The goal is to answer questions about the neural substrate of human spatial information processing, especially mental rotation, size-scaling, and scanning. The program aims to determine whether separate cognitive processes underlie these three abilities, or whether a single visual information processing ability is common to all three. Further experiments will assess the role of spatial reasoning in real-life tasks such as topographic orientation and the understanding of mechanical devices. Clinical and experimental data will be used to clarify the nature and degree of the localization of brain mechanisms underlying spatial transformations.

Approach: A series of cognitive tasks has been designed and validated for use with brain-damaged individuals. These tasks have been validated on normal subjects and screened to avoid a variety of possible artifacts when used with brain-damaged subjects. Associations and dissociations among spatial transformation abilities, as measured by these cognitive tasks, will indicate features of the underlying functional architecture of spatial knowledge and reasoning. These laboratory-based tests will be used in conjunction with realistic tasks and clinical data on lesion sites to discover the specific roles of spatial abilities in ecologically valid settings, and to obtain more precise knowledge of cerebral localization of these functions.

Progress: A core subset of tasks has been selected and prepared specifically for use with patients. Tasks to assess specific mental rotation, mental scanning, and mental size-scaling abilities in targeted clinical populations are now ready for use, and are being used to test brain-damaged patients and age-matched controls. A detailed case study is being conducted of one patient who shows a striking dissociation between image-generation and image-transformation abilities. This case-study will be particularly important in testing recent theoretical ideas about the existence of two cortical visual systems (Ungeleider & Mishkin) and the visual/spatial distinction Baddeley).

TITLE: Interactive Activation Models of Perception and Comprehension

PI: Jeffrey L. Elman
University of California
Department of Linguistics
(619) 452-2536

R&T PROJECT CODE: 442a542 CONTRACT NO: N0001485K0076

CURRENT END DATE: 30 NOV 1987

Technical Objective: Work toward computationally sufficient, biologically plausible, and behaviorally adequate accounts of human information processing skills in visual and auditory language processing.

Approach: Computer simulations of interactive activation mechanisms constructed out of simple processing elements are used to model psychological processes of word recognition. Programmable connections are being used to increase computational power. The information processing behavior of the simulations is compared to what is known from previous research about how humans do the tasks.

Progress: Rumelhart's back-propagation algorithm for learning in connectionist networks has been applied to the problem of learning to imitate a given input speech sample. This method has proven successful. A demonstration audio tape of the system's performance has been produced. Further work is being conducted to characterize the role of "hidden" feature-detection units in speech processing. Several papers have been completed, including "The TRACE model of speech perception" (in press, Cognitive Psychology); "Perceptual interactions in two-word displays" (in press, Journal of Experimental Psychology: Human Perception and Performance); and "Putting knowledge in its place: A scheme for programming parallel processing structures on the fly" (Cognitive Science, vol. 9, 113-146).

TITLE: Expertise and Its Acquisition

PI: James J. Staszewski
Carnegie Mellon University
Department of Psychology
(412) 268-2781

R&T PROJECT CODE: 442a549 CONTRACT NO: N0001485K0524

CURRENT END DATE: 14 NOV 1987

Technical Objective: The proposed research addresses three basic issues: What is expertise? That is, how can experts be distinguished from novices in terms of cognitive structures and processes? Who can become an expert? Does exceptional performance imply a special talent, or can ordinary people be trained to extraordinary levels of performance? How does expertise develop? What factors determine the rate of skill development and the upper bounds of performance? This research proposes to extend previously supported work which has made unique contributions to our understanding of the details of exceptional skill learning under long-term training regimes.

Approach: The research strategy is unique within cognitive psychology. A few subjects are monitored closely as they develop expert-level cognitive skills through hundreds of hours of carefully controlled laboratory practice. Performance is assessed through a variety of tailored methods, including verbal protocol analysis, experimental hypothesis testing, quantitative performance measures, and computer simulation modeling.

Progress: Two extended experiments on the development of expertise have been completed. In the first of these, a college undergraduate with normal abilities increased his digit-span to 110 digits over 800 hours of controlled practice. This is more than 10 times the maximum performance previously recorded by the world's leading "memory experts." In the second study, two normal subjects practiced mental calculation for 250-300 hours. They attained levels of performance comparable to the best "lightning calculators" ever reported. Numerous experiments were conducted to analyze how these subjects achieved such exceptional performance. Although the results of these experiments need to be further tested for generality, there are good theoretical reasons to believe that they point to general principles of expertise in many fields: Expertise entails an effective increase in working memory capacity due to rapid pattern recognition, rapid and reliable use of memory storage and retrieval strategies, and practice-related speed-up of the execution of such strategies.

TITLE: Coping with novelty and human intelligence

PI: Robert J. Sternberg
Yale University
Psychology
(203) 432-4633

R&T PROJECT CODE: 4422534 CONTRACT NO: N0001485K0589

CURRENT END DATE: 31 AUG 1988

Technical Objective: The goal of this research program is to isolate from the standard performance components of problem-solving the parameters that measure the ability to deal with novelty, and in particular relevant novelty in counterfactual reasoning.

Approach: Converging operations are used in three domains and in multiple tasks within each domain to establish the construct validity of the operationalizations of the ability to cope with novelty in counterfactual reasoning. Internal and external validation are used to ensure both the satisfactory isolation of the relevant parameters, and the convergent and discriminant validity of the parameters with respect to established psychometric measures. By isolating the parameters that bear specifically on the ability to deal with novel problems, it will be possible to integrate a theory of this ability with existing ability theories derived from psychometric and cognitive research.

Progress: Experiments have been completed that explore the importance of novelty in verbal analogy, series completion and classification tasks, as well as prediction and post-diction tasks. Experiments are underway on geometric analogies, geometric series and geometric classifications. Research has been initiated on a verbal cloze procedure in which the subject must take account of novel (counterfactual) information and on a bridge-playing task that explores the impact of novel rules on expert and novice players. Numerous publications including: Tetewsky, S.J. & Sterberg, R.J. (1986) Conceptual and lexical determinants of nonentrenched thinking. Journal of Memory and Language, 25, 202-225.

TITLE: Computer Based Assessment of Cognitive Abilities

PI: Earl B. Hunt
University of Washington
Department of Psychology
(206) 543-8995

R&T PROJECT CODE: 4422538 CONTRACT NO: N0001486C0065

CURRENT END DATE: 15 SEP 1990

Technical Objective: The research objective is to conduct studies of individual differences in the ability to coordinate visual-spatial, verbal, auditory, and motor performance, including performance in dynamic tasks, and to determine whether there is an ability to coordinate information received across these modalities that is over and above the ability to deal with each modality separately. Such differences may reflect basic differences in individual cognitive capacities.

Approach: Performance on multi-component tasks requiring coordination of information from multiple sources employing different modalities will be investigated using computer-based presentation and measurement. Carefully designed repeated measures experiments will be complemented by analysis of covariance procedures.

Progress: Based on test-development work previously sponsored by NPRDC, dynamic spatial abilities to reason about objects in motion have been shown to differ significantly from conventional static measures of spatial ability. Factors contributing to the difficulty of such items, which correspond to individual differences in the display features used as the basis of responding, have now been investigated. A task that is an excellent indicator of attention control has been identified, shown to be largely independent of general information processing, and highly reliable within a day (.95). Day-to-day reliability is much lower (about .7), a finding with important practical implications for testing. Investigations of the ability to represent large-scale space are in progress, as are studies of combined verbal and dynamic visual tasks.

TITLE: Individual Differences in Learning and Cognitive Abilities.

PI: Phillip Ackerman
University of Minnesota
Psychology
(612) 625-9812

R&T PROJECT CODE: 4422543 CONTRACT NO: N0001486K0478

CURRENT END DATE: 31 JUL 1989

Technical Objective: To provide the empirical basis for development of a comprehensive model of individual differences in learning and for further unification of the experimental (information processing theoretic) and the psychometric (ability theoretic) approaches to the study of cognitive capacity.

Approach: Four series of studies will be carried out which combine experimental and psychometric methodologies to achieve the project objectives. Subjects will be practiced extensively in a set of cognitive tasks, and factor-analytic methods will be used to assess the nature of the cognitive skills that change as a function of training. A symposium will be run to disseminate results, and to stimulate inter-disciplinary communication.

Progress: Experiments have supported the theoretical position that an equivalence exists between three phases of skill acquisition and three commonly used classes of cognitive/intellectual measures of individual differences (tests of general intellectual ability, tests of perceptual speed, and tests of psychomotor ability.) P.L. Ackerman (1987) Individual differences in skill learning: an integration of psychometric and information processing perspectives. Psychological Bulletin, 102, 3-27. And P.L. Ackerman Determinants of Individual Differences during Skill Acquisition. (Under review.)

TITLE: Imagery Processing in the Brain:
What Neural Networks Compute

PI: Stephen M. Kosslyn
Harvard College
Dept. of Psychology
(617) 495-3932

R&T PROJECT CODE: 4422551 CONTRACT NO: Not yet assigned

CURRENT END DATE: 09 NOV 1988

Technical Objective: The research objective is to conduct studies of component processes involved in visual mental imagery, using four different kinds of research to converge on a comprehensive theoretical formulation which will relate the cognitive functions involved with their neural system substrates.

Approach: The approach combines studies of visual imagery component processing subsystems in normal subjects and in patients with damage to one hemisphere of the brain, using tasks specially designed for these purposes; computer simulation work aimed at developing a computational model to account for normal imagery processing and selective imagery deficits following brain damage; and preliminary studies using Brain Electrical Activity Mapping in an effort to obtain convergent evidence for inferences drawn from the other types of data.

Progress: This contract is new in FY1988.

Outside Funding: AFOSR

COGNITIVE SCIENCE

CLUSTER 2

KNOWLEDGE, SKILL AND EXPERTISE

TITLE: Learning Problem Solving Skills from Studying Examples

PI: Michelene Chi
University of Pittsburgh
Learning Research & Development Center
(412) 624-2982

R&T PROJECT CODE: 442a539 CONTRACT NO: N0001484K0542

CURRENT END DATE: 30 SEP 1988

Technical Objective: This research is an investigation of the relationship between processes students employ in studying worked examples in a physics textbook and their later problem-solving performance.

Approach: A controlled instructional experiment will be conducted in which students of matched ability and background will study material with and without worked examples and will be tested on problems of systematically varied characteristics. Protocols of problem solving and other information on the studying process will be used to identify the strategies of more successful students. This information, together with the results of prior research on the nature of problem solving expertise, will be used to construct instructional examples for further experiments.

Progress: Analyses to date have shown that the more successful problem solvers are those who elaborate to a much greater extent than do less successful problem solvers. Furthermore, the content of these elaborations can be reliably coded for the additional knowledge they provide, beyond what is stated explicitly in the text. Examples of categories of elaboration are implication, goal-induction, and condition-induction. These types of elaborations may provide self-tests on the student's understanding, as well as ways to scope particular problem-solving procedures by "cross indexing" different example problems. Differences in the ways good and poor students refer to example problems in finding solutions to new problems have also been identified.

TITLE: Understanding and Use of Knowledge in Problem Solving

PI: James G. Greeno
The Regents of the University of California
Education
(415) 642-4206

R&T PROJECT CODE: 442a544 CONTRACT NO: N0001485K0095

CURRENT END DATE: 30 NOV 1987

Technical Objective: This research investigates conceptual changes required for mastery of technical and scientific domains such as those taught in Navy technical training. The research will provide computer models of the developing knowledge representations that underlie such change. It will characterize the mechanisms responsible for such changes in knowledge.

Approach: One line of research models the construction of new knowledge representations for classical insight problems and thereby determines how common-sense reasoning is used in problem solving. Another line of research is based on observations of learning about DC circuits. Models of such learning are formulated using theories of qualitative reasoning and existing results on human proof construction and knowledge representation for DC circuits.

Progress: The levels of knowledge used in different stages of solving insight problems have been characterized: (1) specific knowledge of problem solving procedures; (2) functional knowledge of requisite conditions and consequences, and (3) newly generated functional knowledge that is inferred. Computer programs have been implemented that simulate the solution of insight problems. Experiments are in progress that will determine whether these distinctions will account for individual differences in problem solving success.

TITLE: Analogical Processing and Experiential Learning in Physical Domains

PI: Dedre Gentner
University of Illinois
Department of Psychology
(217) 333-1529

R&T PROJECT CODE: 442a551 CONTRACT NO: N0001485K0559

CURRENT END DATE: 31 AUG 1988

Technical Objective: The goal is to formalize and test a theory of the role of analogy and similarity in learning about physical systems. The investigators will develop a computational account of how people access and process information about similarity and analogy, and how these processes interact during learning about physical systems and processes. They will test formal models of knowledge about physical systems and of related learning processes, including coherence-driven learning.

Approach: A variety of research techniques will be used, including psychological experiments to investigate the processing of analogy and similarity, computer simulation of analogical reasoning, and analyses of the conditions of learning about physical systems and processes.

Progress: Experiments and data analysis are continuing on the topics of device learning and analogical transfer. Experiments are beginning on analogical reminding and comprehension. Previous work on the hydraulic analogy in electricity is being extended to heat and temperature. Cognitive simulation of concept learning by literal similarity is being carried out in preparation for a series of experiments on sequential concept learning. Kenneth Forbus and Brian Falkenheimer presented a paper at AAAI on "The Structure-Mapping Engine."

TITLE: The Psychological Reality of Meta-level Problem Solving and Skill Acquisition

PI: Kurt VanLehn
Carnegie Mellon University
Department of Psychology
(412) 268-3790

R&T PROJECT CODE: 442a558 CONTRACT NO: N0001486K0349

CURRENT END DATE: 31 OCT 1987

Technical Objective: The purpose of the proposed research is to explain how people learn cognitive skills by solving problems and by receiving formal instruction. The PI's past research has led to a detailed computational model of the learning of arithmetic skills. The proposed work aims to extend and test that theory in several ways: The PI will develop a general theory of the role of local problem-solving in learning.

Approach: A set of explicit hypotheses will be formulated to attempt to explain existing data on cognitive skill learning. A computer model will be written which simulates the mental representations and cognitive processes hypothesized by the theory. This model will generate extremely detailed predictions of human learning and problem-solving performance. Additional computer programs will be used to compare these detailed predictions with records of actual human performance.

Progress: A detailed study of flexibility in problem solving has been completed. This study was based on an existing database of nonverbal, step-by-step problem solving protocols in the domain of multicolumn subtraction. Protocols from 22 students were examined, and 7 of these showed extremely variable response patterns. That is, they did not follow the textbook procedure or any other rigid procedure. This degree of flexibility could not be modeled by any kind of stack architecture; thus, the data rule out a large class of possible models. Two alternative models were proposed which might account for the data, a goal-tree architecture, and goal-agenda architecture. Both of these were implemented as computer-based models, and their predictions were compared with the data. The goal-tree architecture was not able to reproduce the range of flexibility of students' behavior; the goal-agenda architecture (a restricted blackboard architecture) was able to account for the data. Project completed.

TITLE: Expert Planning Processes in Writing

PI: John R. Hayes
Carnegie Mellon University
Department of Psychology
(412) 268-2781

R&T PROJECT CODE: 442c005 CONTRACT NO: N0001485K0423

CURRENT END DATE: 14 JUN 1988

Technical Objective: The goal is to investigate a general theory of the cognitive processes involved in writing, especially processes of goal-setting, goal-management, and planning. The proposed work aims to specify the subprocesses of planning (goal-setting, goal-generation, and organization) and to determine how novice and expert writers adapt, develop, and reorganize their ideas during the writing process.

Approach: A series of experimental studies will be carried out. These studies involve innovative methods of eliciting planning protocols from novice and expert writers. The performance of different subjects will be compared on identical complex planning tasks, in order to isolate planning skills from other writing skills. Expert and novice plans will be theoretically characterized at several different levels, ranging from global to very specific. Different writers' ability to adapt to their intended audience will be assessed.

Progress: Writing is analyzed as an ill-defined construction task. The role of feedback from intermediate results is particularly important in the construction process. Experts differ from novices, and effective from ineffective writers, in their ability to adapt content to an audience under multiple constraints. These qualitative observations are being refined by using measures of time-investment and quality of planning. Goal-networks are being used to model opportunism and restructuring in the presence of competing goals. Protocol studies of expert and novice writers have highlighted the "knowledge effect" -- extensive knowledge in a domain may actually interfere with effective communication to less knowledgeable audiences. This effect has been the topic of two recent papers: J.R. Hayes, "If it's clear to me it must be clear to them" (March '86 Conference on College Composition & Communication); J.R. Hayes, "Is this text clear? -- How knowledge makes it difficult to judge" (April '86 meeting of the American Educational Research Association).

TITLE: Solving Algebra Story Problems

PI: Dennis Kibler
University of California, Irvine

(714) 854-5951

R&T PROJECT CODE: 442c006 CONTRACT NO: N0001485K0373

CURRENT END DATE: 30 JUN 1988

Technical Objective: The objective is to model the process of solving algebra word problems, including the way in which those processes draw upon multiple sources (types) of knowledge and the use of analogy. It is expected that this will suggest hypotheses about the process of learning such problem solving skills and about the way in which they can be effectively taught in automated tutoring systems.

Approach: Human protocol data are to be collected on a carefully designed set of problems. A computer simulation model of the problem solving process will be built and tested.

Progress: Large numbers of written problem solving protocols were collected on isomorphic pairs of problems and analyzed. Very diverse problem solving process and extensive use of model-based reasoning were revealed. A revised version of the technical report of this phase of the work is expected to be published soon in Cognition and Instruction: Hall, Kibler, Wenger, & Truxaw, Exploring the episodic structure of algebra story problems. The computer simulations have now been designed. A background literature review for the project grew into: E. Wenger, Artificial Intelligence and Tutoring Systems, Morgan Kaufmann, 1987.

TITLE: Schemas in Mathematics Problem Solving

PI: Sandra Marshall
San Diego State University Foundation
Psychology
(619) 229-2695

R&T PROJECT CODE: 442c010 CONTRACT NO: N0001485K0661

CURRENT END DATE: 31 AUG 1988

Technical Objective: The project objective is to produce a psychological model of the teaching and learning of mathematical problem-solving skills, incorporating three components: a model of knowledge in memory, a model of learning, and a model of instructions. The model of instruction, unlike most, will be explicitly related to the psychological models of learning and memory for this problem domain.

Approach: The underlying semantic structures, or schemas, of mathematics word problems used in school texts, Navy remedial courses, and standardized tests will be analyzed and related to item difficulty in mass test data. Computer simulation models for the process of problem solving using these schemata will be produced. Student knowledge of problem schemas and errors in their use will be investigated. Computer models of both correct and erroneous student performance will be produced to provide a basis for designing experimental instruction in conjunction with computer modeling of the learning process.

Progress: A survey of the types of word problems used in remedial college set- tings has been completed, confirming that the set of schema representa- tions previously established for the instruction of children also describes the problems presented in adult remedial instruction. Experimental data on the word problem solving performance of the subject populations being used has been collected. Propositional encoding of the word problems has been done for the purpose of computer simulations of word problem performance, and schemata have been fully specified to serve as a basis for computer models of student performance.

TITLE: Comprehension processes in mechanical reasoning

PI: Marcel A. Just
Carnegie Mellon University
Psychology
(412) 578-2791

P&T PROJECT CODE: 442c014 CONTRACT NO: N0C01485K0584

CURRENT END DATE: 31 JUL 1988

Technical Objective: Investigate individual differences in mechanical reasoning ability. Build a computer simulation model that characterizes individual differences.

Approach: Modified versions of texts from BASIC MACHINES, a Navy training manual, will be used in the research. Characteristics of the text, the diagrams, and the relation between the two, will be experimentally varied. Records of eye movements by readers will provide data for making inferences about processing, particularly identification of points of maximum processing load. A computer simulation will be produced that builds up a "mental model" of the mechanism. This simulation will be based upon existing simulations of text processing and of the processing of spatial ability test items.

Progress: A manuscript has been prepared for publication on individual differences in mechanical reasoning ability. A computer simulation model that characterizes individual differences is presented. The basis of individual differences in mechanical reasoning was found to lie in three factors: 1) discrimination of relevant from irrelevant attributes of the situation2) consistency of rule use, and 3) ability to combine rules involving different attributes. In addition, animation facilities have been prepared for further experimentation on the contribution of animation to mechanical comprehension.

TITLE: Stability in Conceptual Belief

PI: Paul J. Feltovich
Southern Illinois University at Carbondale
Department of Medical Education
(217) 782-7878

R&T PROJECT CODE: 4422547 CONTRACT NO: N0001488K0077

CURRENT END DATE: 01 DEC 1989

Technical Objective: Research objectives are to develop a Conceptual Stability Scheme for characterizing misconceptions and for predicting their stability, to apply this Scheme in predicting the stability of misconceptions about the cardiovascular system, to develop a Conceptual Stability Battery for determining the actual stability of each misconception among students, and to create computer network models of selected misconceptions to help account for variation in stability.

Approach: The approach uses a combination of cognitive structure and process analyses based on the Conceptual Stability Scheme, empirical verification of the stability predictions using the Conceptual Stability Battery, and computer network modeling of selected misconceptions. This combination will permit insights into the structure and causes of misconceptions about complex phenomena both through theoretical and empirical studies of skilled human subjects and through manipulations of computer network models of the structures and processes which underlie those misconceptions.

Progress: This contract is new in FY1988.

TITLE: Investigations of Human Question Answering

PI: Arthur C. Graesser
Memphis State University
Dept of Psychology & Mathematical Sciences
(901) 454-2742

R&T PROJECT CODE: 4422548 CONTRACT NO: N0001488K0110

CURRENT END DATE: 27 DEC 1989

Technical Objective: This project aims to test, modify, and expand a model of question-answering proposed by Graesser and Clark. The model specifies (1) the information sources tapped during question answering, (2) the symbolic search procedures used to locate information, and (3) the process of converging upon relevant information to be used in generating the answer.

Approach: Psychological experiments will be conducted to test the predictions of the model about the salience, judged quality and latency of production of answers to questions that are asked about narrative texts, expository texts, and general knowledge. Detailed formal representations of the knowledge structures resulting from text reading and comprehension will form the basis of these predictions. Computer simulation models of aspects of the question answering model will be developed.

Progress: This contract is new in FY1988.

TITLE: Knowledge and Process for Design

PI: James G. Greeno
Leland Stanford Junior University
School of Education
(415) 723-0433

R&T PROJECT CODE: 4422549 CONTRACT NO: N0001488K0152

CURRENT END DATE: 31 JAN 1990

Technical Objective: The research objective is to conduct studies of the design problem-solving process which will yield data for developing a model that characterizes the contents of the problem space and the problem-solving processes involved in design tasks, focusing on generative processes of formulating and modifying problem goals and plans and on using information from multiple sources.

Approach: The approach uses two kinds of tasks. In one, subjects design instruction, given some goals and constraints. In the other, subjects analyze and evaluate prepared instruction. Empirical studies and psychological experiments will be conducted in which goals and constraints on design problems are manipulated, and in which the availability of knowledge relevant to the design task is varied. Instructional design topics to be studied include training in the operation of artificial devices and academic instruction in statistics.

Progress: This contract is new in FY1988.

TITLE: Knowledge and Processes for Design

PI: Peter Pirolli
University of California, Berkeley
Department of Education
(415) 652-4560

R&T PROJECT CODE: 4422550 CONTRACT NO: N0001488K0233

CURRENT END DATE: 31 DEC 1989

Technical Objective: The research objective is to conduct studies of the design problem-solving process which will yield data for developing a model that characterizes the contents of the problem space and the problem-solving processes involved in design tasks, focusing on generative processes of formulating and modifying problem goals and plans and on using information from multiple sources.

Approach: The approach uses two kinds of tasks. In one, subjects design instruction, given some goals and constraints. In the other, subjects analyze and evaluate prepared instruction. Empirical studies and psychological experiments will be conducted in which goals and constraints on design problems are manipulated, and in which the availability of knowledge relevant to the design task is varied. Instructional design topics to be studied include academic instruction in statistics and training in the operation of an artificial device.

Progress: This contract is new in FY1988.

TITLE: Artificial Intelligence Measurement System

PI: Eva L. Baker
University of California, Los Angeles

(213) 206-1530

R&T PROJECT CODE: 442c022 CONTRACT NO: N0001486K0395

CURRENT END DATE: 30 SEP 1989

Technical Objective: The objective of this contract is to obtain a set of measures appropriate for assessing the performance of AI programs in the areas of natural language understanding, voice recognition, vision, and expert systems.

Approach: Psychometric methods will be refined to permit common scaling of system performance within each area. Specifications for performance at three or more levels of complexity within each area will be prepared. Appropriate test items will be drawn from prior work testing human cognitive capacities. Item analysis techniques will be used to detect significant deviations from patterns of item easiness and difficulty that characterize human performance, in order to detect peculiar limitations of an AI system.

Progress: A natural language understanding sourcebook and database are being developed that contain exemplars, discussion, and bibliographic references for critical linguistic issues. Existing machine vision systems have been analyzed and tabularized along dimensions of image attributes, perceptual primitives, knowledge utilization, object representation, and control strategy, and a block diagram of a general purpose vision system has been synthesized. Preliminary criteria for evaluation of expert system shell tools with respect to domain applications have been developed, including usefulness of the tool, ability to facilitate integration of new knowledge, suitability of knowledge representation, and comparison of performance of different tools and different experts in a domain.

Outside Funding: DARPA

TITLE: Conf. on speaking, reading, thinking and development

PI: Wallace Russell
University of South Florida
College of Social and Behavioral Sciences
(813) 974-2503

R&T PROJECT CODE: 442a560 CONTRACT NO: N0001487G0210

CURRENT END DATE: 31 DEC 1987

Technical Objective: The objective is to provide a setting in which outstanding researchers in the cognitive sciences can get together to discuss current and expected developments in the application of basic research in cognition.

Approach: The conference will consist both of formal presentations and small group discussions of the focus issues. The results of the small group discussions will be presented to participants as a whole for evaluation and recommendations.

Progress: Participants in the conference have prepared chapters summarizing the work reported. These are currently being edited for inclusion in a volume of conference proceedings.

COGNITIVE SCIENCE

CLUSTER 3

LEARNING AND INSTRUCTION

TITLE: Staffing the Use of LISP Machines for Intelligent Computer-Based Training

PI: Alan Lesgold
University of Pittsburgh
Psychology
(412) 624-7045

R&T PROJECT CODE: 442a524 CONTRACT NO: N0001483K0655

CURRENT END DATE: 15 NOV 1988

Technical Objective: This effort will provide support for research and transition of research results in the area of intelligent computer-based training. The objective is to expand and accelerate research in this area and to provide for a uniform mechanism for transition of research results to development projects.

Approach: A network of researchers in the area of intelligent computer-based instruction will be established. The network will include both basic researchers and applied Navy researchers working with a common suite of hardware and software research tools. This effort will provide a communications network for these researchers, develop and maintain a software library, and arrange for meetings as needed.

Progress: Training materials for the Interlisp-D environment have been developed and workshops have been conducted for the collaborating community of researchers. Software tools, including a general cognitive modeling system, a highly flexible simulation capability, Chips, that permits quick prototyping of tutorial interfaces, and a tutoring system, Bridge, which employs intermediate representations to mediate novices' learning of goal-oriented programming skills, have been developed and made avail- able to other researchers. Explorations of a generalized tutoring architecture have led to advances in both knowledge representation and instructional goal specification. These ideas and tools are being experimentally tested via incorporation in numerous tutoring applica- tions being funded by a variety of sponsors.

TITLE: Skill Acquisition in an Intelligent Tutor

PI: John R. Anderson
Carnegie-Mellon University
Psychology
(412) 268-2788

R&T PROJECT CODE: 442a530 CONTRACT NO: N0001487K0103

CURRENT END DATE: 31 DEC 1989

Technical Objective: The objective of this research is to extend and test a theory of human skill in computer programming, and to use this theory as the student model component of an Intelligent Computer-Assisted Instruction (ICAI) system that is capable of tutoring beginning programmers.

Approach: A specially designed production system (i.e., computer model) was used to model an ideal student being tutored in LISP, a programming language. A "knowledge compilation" or learning feature was added to the production system in order to model both novice and more advanced students accurately. To test predictions from cognitive theory about the learning process, a computerized LISP tutor was constructed that incorporates the following elements: domain-independent tutoring strategies, LISP programming rules for modeling the student, tutorial rules for analyzing student programming code and giving feedback, and practice problems. Experimental tests are in progress.

Progress: Cognitive modeling of students learning LISP, a programming language, was used under a previous contract as the basis for constructing an artificially intelligent tutor. The LISP tutor, a version of which is now available both as a commercial training product and for research purposes, has been shown to be more effective than traditional classroom instruction, and detailed data on student performance have been used to test cognitive skill acquisition theory. Analysis of data from a complete course taught using the original version of the LISP tutor has been completed. Variant tutorial strategies are now in the process of implementation in order to test further hypotheses generated by the ACT theory of cognitive skill learning.

TITLE: Learning about equipment from technical documentation

PI: David E. Kieras
The Regents of the University of Michigan
Department of Engineering Humanities
(313) 763-6739

R&T PROJECT CODE: 442a543 CONTRACT NO: N0001485K0138

CURRENT END DATE: 30 APR 1989

Technical Objective: This work aims to achieve a precise theory of both the cognitive processes that are involved in operating technical devices such as computers or electromechanical equipment and the processes by which technical documentation is read and understood in order to learn to operate such devices. In addition, it aims to understand how previous knowledge of device operation facilitates the learning of new operational tasks in order to provide a principled theoretical basis for the design of training sequences. It is now expanded to include application of the findings in software that critiques the quality of technical documentation.

1498 Approach Computational models based on modeling techniques related to artificial intelligence are developed and tested against data on human learning and transfer of training in the operation of engineered devices such as control panels. Detailed models of comprehension and learning are tested against fine-grained descriptions of human performance in procedural tasks.

Progress: The PI has designed and implemented a new production system interpreter, PPS, which is powerful, yet simple and compact enough to be used as a component in larger models. He has also designed and implemented a general simulator for user-device interaction. He has completed work on modeling how people interpret and use technical documentation in understanding the structure and function of a simple energy-flow device. His data collection lab is on line, and he has conducted preliminary analysis of two data sets on mental modelling of how people learn to operate novel pieces of equipment; he has also finished work on simulation models of this process. Software tools for creating such models have been developed for the Xerox 1108. He has done some work on implications of his theoretical work on mental modelling for application to testing (diagnostic monitoring of cognitive skill acquisition) and to construction of intelligent tutoring systems.

TITLE: Conceptual Change in Problem Solving and Learning

PI: Stellan Ohlsson
University of Pittsburgh
Learning R&D Center
(412) 624-4889

R&T PROJECT CODE: 442a545 CONTRACT NO: NC001485K0337

CURRENT END DATE: 14 NOV 1988

Technical Objective: Goal is to extend, generalize, and test a theory and modeling framework for conceptual change in problem solving. Purpose of this theory is to explain in detail how people progress from novice to expert, that is, to become able to solve problems that they at first found impossible.

Approach: Three series of experiments will be conducted, each involving both empirical and modeling work. Subjects' misconceptions will be diag- nosed; naive problem solvers will undergo short-term training and their short-term cognitive changes will be assessed; follow-up assessments will be used to detect long-term cognitive changes. Data collected under all these conditions will be subjected to quantitative and quali- tative analysis, and will be used to support cognitive modeling efforts.

Progress: Progress under first two years of funding is comprehensively documented in a 65 page report that accompanied renewal proposal. An information processing architecture, called Semantic Information Processor (SIP), is described, along with specific hypotheses that have been introduced in order to derive a working simulation model. This modeling framework is compared to other, similar modeling efforts. Observational studies of proof-finding in geometry have been carried out to obtain specific instances of insight and restructuring in human problem solving. These episodes have been discussed in relation to SIP model. Various charac- terizations of naive physics knowledge have been analyzed in detail necessary for computer simulation and possible treatments in SIP and Qualitative Process Theory (Forbus) compared.

TITLE: Intelligent Multimedia Tutoring for Repair Tasks

PI: Patricia Baggett
University of Colorado
Department of Psychology
(303) 492-6991

R&T PROJECT CODE: 442c001 CONTRACT NO: N0001485K0060

CURRENT END DATE: 30 NOV 1987

Technical Objective: Develop a theory of multi-media intelligent computer-assisted instruction for repair tasks. Test adequacy of proposed knowledge representation to represent knowledge required for repair tasks. Determine optimal instructional strategies for conveying expert knowledge of repair tasks to trainees.

Approach: Implement knowledge representation on a computer system and use to model expert and student knowledge. Conduct experiments in which the strategies for presenting instructional information by computer are systematically varied. Assess student knowledge representations that result from instructional approaches.

Progress: An unexpected experimental finding was obtained: Interactive viewing of instructions, without the opportunity to practice a construction task, was shown to be approximately equal to interactive, user-paced viewing, and superior to passive viewing, when evaluated in terms of performance on a construction-from-memory task. The causes of this surprising result are being examined in additional experiments. In a separate series of experiments, an algorithm based on directed acyclic word graphs was shown to be superior to unaided novice and expert humans in selecting useful names for unfamiliar parts and structures in mechanical devices. Several conference papers and reports were completed, including Baggett & Ehrenfeucht, "Conceptualizing in Assembly Tasks" (Human Factors, in press).

TITLE: Automated tutoring of diagnostic reasoning

PI: Nils Nilsson
Stanford University
Computer Science
(415) 723-9745

R&T PROJECT CODE: 442c003 CONTRACT NO: N0001485K0305

CURRENT END DATE: 31 MAR 1988

Technical Objective: This research is concerned with computational and psychological theory to support intelligent computer-assisted instruction of diagnostic skills. It will formalize a model of diagnostic reasoning, formalize heuristics for computer generation of explanations of diagnostic reasoning, and formalize heuristics for modeling the process of student reasoning. Tutorial programs will be built to realize a variety of tutorial strategies and empirical investigations of their effects will be conducted.

Approach: This research uses artificial intelligence methods to construct both expert systems that do diagnostic reasoning and intelligent tutorial programs. In the expert system, general reasoning processes are separated from specific factual knowledge of the particular subject matter domain. Explanation capabilities and tutorial programs are built around and integrated with the expert system. Performance is compared to human experts and human tutors. The effects of varying tutorial strategies are empirically compared.

Progress: In a sequence of computer programs, basic AI techniques for separat- ing domain facts from a diagnostic procedure (NEOMYCIN) have been demonstrated, and the advantages of this separation for explanation and student modeling have been shown (IMAGE, ODYSSEUS). A corresponding sequence of published articles describe the NEOMYCIN program as a psychological model of diagnosis, as an architecture for representing strategic knowledge, and as a general problem solving method called "heuristic classification". A family of tutoring programs permit various approaches to instruction, ranging from browsing and observation of the expert system to having the student provide high-level strategic instructions to the diagnostic system that implements their details. Overview publication: From Guidon to Neomycin and Heracles in twenty short lessons. AI Magazine, August 1986.

TITLE: Tutoring Expertise

PI: Elliot M. Soloway
Yale University
Computer Science
(203) 436-0606

R&T PROJECT CODE: 442c007 CONTRACT NO: N0001482K0714

CURRENT END DATE: 14 AUG 1988

Technical Objective: This research will test and refine a theory of the knowledge structures and reasoning processes underlying tutorial expertise in the domain of computer programming. Experimental and computer-based modeling of the diagnostic reasoning of effective human tutors will be used to create principles for the design of more effective intelligent tutoring systems.

Approach: Empirical and computer-simulation methods will be applied to describe the reasoning processes of expert tutors. These reasoning processes will be incorporated into an intelligent computer-assisted instructional system for teaching introductory PASCAL programming. The theory of tutorial expertise will be tested by assessing the success of the automated system in diagnosing and remediating students' misconceptions and systematic programming errors.

Progress: Studies of human tutors have been completed and hypotheses about the process of tutorial planning have been formulated on the basis of data analyses. Construction of the computer simulation program is in process.

TITLE: Explanation Building in Learning Complex System Operation

PI: Clayton H. Lewis
The Regents of the University of Colorado
Computer Science Department
(303) 492-6657

R&T PROJECT CODE: 442c009 CONTRACT NO: N0001485K0452

CURRENT END DATE: 30 SEP 1988

Technical Objective: This project aims to develop and test hypotheses about people's understanding and operation of complex computer-based systems. Previous research under this contract has developed and tested a theory of how people construct and use causal explanations of such systems. The new proposed work will extend the testing and refinement of this theory by deriving hypotheses and testing them experimentally. Experimental work will be complemented by AI-based cognitive modeling.

Approach: Operation of computer systems for text and graphics editing are being studied because these systems permit careful experimental manipulation of their characteristics. A simulation model of how people form mental models of such systems has been developed. Detailed, keystroke-level performance protocols are collected. These performance data, along with simulation modeling, are used to test hypotheses about the kinds of inferences people draw about the underlying structure of systems by interacting with them.

Progress: Several conference presentations and technical reports have been produced under this contract. Most recently, a 50-page report was released entitled "Why and How to Learn Why: Analysis-Based Generalization of Procedures." This report argues that people use explanations to organize knowledge about procedures in ways that support generalization. Several possible mechanisms for generating explanations were identified based on AI work. Experiments on human performance showed that one of these mechanisms (modificational analogical generalization) provided a good account of human performance in problems that make few demands on memory for examples.

TITLE: Impact of intelligent computer-assisted instruction

PI: Janet W. Schofield
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Psychology
(412) 624-3068

R&T PROJECT CODE: 442c013 CONTRACT NO: N0001485K0664

CURRENT END DATE: 31 AUG 1989

Technical Objective: The objective of this research is to decide among several possible cognitive process explanations for the fact that readers have very poor ability to judge the adequacy of their comprehension of technical material and to determine whether experimental instructional techniques suggested by those explanations can improve those judgments. Judging the adequacy of one's comprehension is important to the effective self-management of study efforts.

Approach: It is thought that judgments of comprehension may be based upon the superficial coherence of the text and/or the ease of processing the text superficially, whereas answering the inference questions requires constructing a mental model of the situation discussed in the text. Various instructions, types of questions, superficial text characteristics, and orders of testing activities will be experimentally varied to test these hypotheses. The effect of subject-matter expertise will also be explored.

Progress: In the first two years of the project, observations were conducted in the experimental computer tutor classes, in "control" geometry classes, and in two computer science classes. Observations were conducted in other situations of school computer use as well. In addition, extensive interviews with students, teachers, and other project participants were conducted. Computerization of the data files for analysis has begun. One initial report has been written: Schofield and Verban, Computer Usage in the Teaching of Mathematics: Issues which need answers. To appear in D. Grows & T. Cooney (Eds) The Teaching of Mathematics: A research agenda.

TITLE: Reasoning and Comprehension Processes of Language Minority Persons Learning from Text

PI: Richard P. Duran
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Graduate School of Education
(805) 961-3555

R&T PROJECT CODE: 442c015 CONTRACT NO: N0001485K0562

CURRENT END DATE: 30 JUN 1988

Technical Objective: The overall objective of this research is to characterize the cognitive processes of linguistic minority students or trainees as they comprehend and reason from instructional texts. This includes the identification of linguistic structures that are likely to cause difficulty and investigation of the impact of difficulty with these relatively low-level aspects of comprehension upon more sophisticated processing of the content of texts.

Approach: Texts from a variety of subject matter domains will be analyzed with respect to structures at the sentence, inter-sentence and global level (e.g., thesis-evidence or compare-contrast). Quantifiers, qualifiers, conditionals, and linguistic features signaling cohesion among parts of a text will be emphasized. Students will be presented with academic tasks varying in the demand for sophisticated cognitive processing and will be asked to "think aloud" as they perform the tasks in order to identify points of processing difficulty. Student expertise in the subject matter of the texts will be varied also. Experimental tests of the hypotheses developed will be pursued in future years.

Progress: Textbook passages were selected from introductory and advanced texts on oceanography and on cognitive psychology. Scripts have been designed for collecting structured verbal protocols during students' attempts to understand the passages. A set of computer programs has been developed to control subject-task interactions. Reading and response times, as well as answers to objective comprehension test items, are being recorded for subjects with differing degrees of familiarity with English and Spanish.

TITLE: Research on Human Tutorial Dialogue

PI: Barbara A. Fox
The Regents of the University of Colorado
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(303) 492-6305

R&T PROJECT CODE: 442c017 CONTRACT NO: N0001486K0105

CURRENT END DATE: 31 DEC 1988

Technical Objective: The goal is to test and refine a theory of the processes of human tutorial dialogue, including conversational repair, tutor intervention, and strategies of linguistic communication. The role of each of the following variables will be assessed: mode of communication (face-to-face vs. computer-mediated); subject matter being taught; and the student's level of competence. The proposed theoretical and experimental work will form the basis for improved design principles for natural-language interfaces to intelligent tutoring systems.

Approach: Tutorial interactions at the University of Colorado will be videotaped. Both natural and computer-mediated tutorial dialogues will be recorded. Beginning and intermediate students in LISP-programming and algebra classes will be studied. Face-to-face and computer-mediated modes of communication will be used for different groups of students. A detailed transcript of each dialogue will be made, using a coding system which has been developed in earlier research. These transcripts will be analyzed to determine the effects on dialogue structure of the various conditions of instruction. This analysis will address specific questions concerning communicative trouble and repair, the role of multimedia knowledge representation, and the structure and role of tutorial interventions.

Progress: Research has been initiated on the communication processes involved in human-human tutoring. This research is using psychological and linguistic methods to characterize dialogue structure, the use of multiple knowledge representations, the types of tutor interventions, and the effects of the student's level of understanding on the nature of tutorial interventions. Preliminary findings have serious implications for the design of computer-based tutors. Effective human-human tutorial dialogue seems to depend to a great extent on locally managed, emergent structures, rather than pre-planned, hierarchical structures.

TITLE: Feedback Effects in Computer-Based Skill Training

PI: John Levine
University of Pittsburgh
Psychology
(412) 624-7462

R&T PROJECT CODE: 442c021 CONTRACT NO: N0001486K0569

CURRENT END DATE: 30 SEP 1988

Technical Objective: This research will systematically investigate the effects of performance feedback variables upon trainee performance in computer-based tasks requiring substantial practice. Both intrapersonal feedback - providing information about past, present, and probable future performance - and interpersonal feedback - comparing the trainee's own performance with others' performance. The goal is to identify computer implementable feedback procedures that optimize student performance.

Approach: Computerized training situations developed for Schneider's research on the training of automatized skill components will be used in the research. Various presentations of information on performance will be compared in effectiveness as will pre-determined variations in reported comparative and predictive performance levels.

Progress: A literature review was conducted and supplemented by telephone inquiries, indicating that very little related work has been done. A category search experimental paradigm for the investigations was successfully implemented and an initial experiment on the effects of reaction time feedback has been conducted, with supplementary questions to subjects concerning their impressions of performance quality and their attributions. Analyses are in progress, but it appears now that reaction time feedback has substantial effects on performance and that interspersed question periods have no effect so that their use can be continued.

TITLE: A model of self-generated explanation in skill acquisition

PI: Kurt A. VanLehn
Carnegie-Mellon University
Psychology
(412) 268-4964

R&T PROJECT CODE: 442f001 CONTRACT NO: N0001488K0086

CURRENT FND DATE: 31 DEC 1991

Technical Objective: This project will produce a computer simulation model of the process of student learning of physics problem solving from example problems in text. It will test the hypothesis that self- generated explanations of the steps in example problems produces more effective learning, a hypothesis based on previous empirical observations of individual differences in study processes and ultimate learning success. The Carnegie Symposium on Architectures for Intelligence will produce a book in which leading theorists discuss the foundational assumptions of such models.

Approcch: The project will use student protocol data previously collected and transcribed by Chi & Glaser. A vocabulary of 50-100 formal codes will be developed to code protocol data of problem solving acts at a fine level of detail, and the protocols will be coded, providing a formal basis for testing the fit of the model to protocol data. A simulation model will be developed that generates sequences of action in these same terms. The simulation program will have 6 major modules: 1) primitives corresponding to the protocol coding that establish the grain-size of modeling; 2) a non-analogical problem-solver for single-schema (simple) problems; 3) explanation of problem statements that classifies problems appropriately into types; 4) explanation of problem solutions that justifies problem solving actions; 5) analogical problem solving and learning; and 6) a problem solver for complex multi-schema problems. The model will be fitted to the protocol data, seeking a theoretical explanation for individual differences in learning success.

Progress: This contract is new in FY1988.

TITLE: Explanation-based acquisition of electronics knowledge

PI: David Kieras
Regents of the University of Michigan
Technical Communication
(313) 763-6739

R&T PROJECT CODE: 442f002 CONTRACT NO: NC001488K0133

CURRENT END DATE: 31 OCT 1990

Technical Objective: The project will construct an AI system for learning electronics concepts from explanatory text and will conduct cognitive psychology experiments on human learning in the same context. The results of the two types of work will be integrated in the form of a cognitive model that explains human acquisition of knowledge in this domain in terms of the mechanisms in the AI system.

Approach: The AI model, already partially developed, will have the following characteristics. A circuit diagram and associated explanatory text are translated into propositional form. The circuit diagram is "understood" by being characterized as instantiations of general circuit schemata. Explanations, which are generally statements of causal relations between changes in the circuit states, are processed by accounting for the statements in the explanations based on known rules of circuit behavior, filling in missing inferential steps. This process then becomes the basis for the formation of new, more complex circuit schemata that result in faster understanding of future circuits. The AI system will then be elaborated into a cognitive model that provides prediction metrics such as the number of production rules fired and the number of propositions processed. Psychological experiments will be conducted to test the predictions generated by the model regarding the effects of varied explanatory materials.

Progress: This contract is new in FY1988.

TITLE: Explanation and Decision Making in Planning

PI: Kristian J. Hammond
The University of Chicago

(312) 702-1571

R&T PROJECT CODE: 4422003 CONTRACT NO: N0001488K0295

CURRENT END DATE: 14 NOV 1990

Technical Objective: The objective is to develop a theory of case-based reasoning for problem-solving tasks that addresses questions of memory organization, of decision-making as it applies to the selection of past cases for use in problem-solving, and of the role of explanation formation in learning from case experience.

Approach: Appropriate problem solving domains, such as a simplified bridge design task, will be used as the basis of investigation. An AI program will be developed that constitutes an elaborate hypothesis about the nature of the case-based reasoning process involved in solving such problems. The following major parts to this program are planned: a Problem Anticipator that recalls planning problems in past similar situations, a Case Retriever that searches for a plan that satisfies as many goals as possible while avoiding anticipated problems, a case Modifier that alters the retrieved plan to satisfy additional goals, a Plan Repairer that generates causal explanations for failure and repairs plans on that basis, a Case Storer that indexes plans in memory according to the goals they satisfy and the problems they avoid, and a Blame Assigner that uses causal explanations of failure to identify features to predict and avoid similar failures in the future. Psychological experiments will be used to investigate alternative hypotheses that arise as design issues in the model.

Progress: This contract is new in FY1988.

TITLE: The Induction of Mental Structures While Learning to Use Symbolic Systems

PI: Thomas G. Bever
University of Rochester
Department of Psychology
(716) 275-3213

R&T PROJECT CODE: 442f005 CONTRACT NO: N0001488K0336

CURRENT END DATE: 30 APR 1991

Technical Objective: The research objective is to explore the emergence of implicit mental structures (such as linguistic grammars or mental models of machine operations) during the solution of explicit problems. The investigator has proposed a problem-solving theory of the acquisition of implicit structure which he will test with a series of experiments using an artificial symbolic system.

Approach: A series of experiments will be conducted to test hypotheses derived from the investigator's theory of the formation of implicit mental structures during the solution of explicit problems. In addition to attempting to improve the efficiency of the basic paradigm used in a pilot study, the experiments will investigate: implications, for learning, of conflicting regularities within mapping systems for internal perception and production mechanisms; differences between perception and production in learning; and extensions of the paradigm to investigate implications of fuzzy feedback, effects of error messages, and modelling of the acquisition of behavior and structure.

Progress: This contract is new in FY1988.

TITLE: Human Plausible Reasoning and Learning: Development of a Computational Model and a Unified Theory.

PI: Ryszard S. Michalski
George Mason University
Computer Science
(703) 323-2713

R&T PROJECT CODE: 442f006 CONTRACT NO: N0001488K0397

CURRENT END DATE: 14 MAY 1990

Technical Objective: This research aims to provide computational models of the way in which humans learn and reason with imprecise, incomplete and/or indirectly relevant premises.

Approach: A unified theory of human plausible reasoning and inductive learning will be developed in the form of a computational model. This will build upon the Collins and Michalski "core theory" of human plausible reasoning, upon Michalski's "two-tiered method" for representing flexible context-dependent concepts, and Medin's "multi-criterion patch model" of inductive learning. Further experimental tests of human performance will be conducted in order to test the computational theory against human performance.

Progress: This contract is new in FY1988.

TITLE: Cognitive and instructional theories of impasses in learning

PI: Alan Lesgold
University of Pittsburgh
Psychology Department
(412) 624-7045

R&T PROJECT CODE: 4422539 CONTRACT NO: N0001486K0361

CURRENT END DATE: 30 APR 1988

Technical Objective: The central purpose of the proposed research is to optimize the learning of complex cognitive skills. Current cognitive theories formulate the task of curriculum design as the teaching of many component skills to the point of automaticity. The component skills are then assumed to combine in a straightforward way to produce the complex skill. A long history of research in developmental psychology, as well as some recent work on skills such as medical diagnosis, indicates that a restructuring of knowledge, not a simple concatenation of skills, may be necessary before trainees can progress to higher performance levels. This project aims to elaborate and test a comprehensive theory of the possible relations between component skills (prerequisites) and the complex skills they support. Such a theory will form the basis of larger knowledge-structures for intelligent tutoring systems, moving beyond single concepts to course- and curriculum-sized structures.

Approach: The learning of a range of perceptual skills, ranging in complexity from simple, highly controlled laboratory tasks to tasks approaching the complexity of passive sonar interpretation, will be studied using techniques of experimental psychology, cognitive modeling, and intelligent tutoring. Impasses in learning will be related to subjects' mental models or personal theories of the causal substrate of perceptual patterns.

Progress: A general capability to design and present experiments of the type required by the project has been developed. Visual presentations of recognition stimuli can be obscured by multiple layers of noise varying in both quantitative and qualitative characteristics. An initial series of three experiments has been done in order to identify situations that provide clear, replicable examples of the impasse phenomena in learning that are to be investigated in the remainder of the research project.

TITLE: A Proposed Research Center For The
Study of Intelligent Tutoring Systems
In Teaching of Quantitative Reasoning

PI: Mark Siegel
University of the District of Columbia
Department of Psychology
(202) 282-2152

R&T PROJECT CODE: 4422552 CONTRACT NO: Not yet assigned

CURRENT END DATE: 30 JUN 1989

Technical Objective: The potential of existing ICAI software and the possibility of collaborative relationships with other researchers will be explored with the intent of developing an R&D program directed at an instructional approach to improving the quantitative reasoning skills of students in an Historically Black College as well as skills of similar military trainee populations.

Approach: The PI will obtain existing ICAI software and establish contacts with existing ONR research contractors active in this area. He will review and explore the design and programming of that software and plan a more specified research program for future consideration.

Progress: This contract is new in FY1988.

TITLE: Improvements of the Intelligent Maintenance Training System, with a Second Application

PI: Douglas M. Towne
University of Southern California
Behavioral Technology Laboratory
(213) 540-3654

R&T PROJECT CODE: 4428011 CONTRACT NO: N0001487C0489

CURRENT END DATE: 30 SEP 1988

Technical Objective: The objective of this contract is to develop an experimental training system for intelligent computer-assisted maintenance training that includes both (1) computer-aided methods for analysing the practice requirements of maintenance training and (2) a general training system that will provide individualized selection and sequencing of exercises and an automated tutor that will coach students during exercises. This system will incorporate the Navy's existing General Maintenance Training Simulator and will be implemented for Blade Fold Rotor Brake (helicopter) maintenance training.

Approach: Relations among training exercises and required skills will be represented in a database, constructed with computer-aided analyses. Artificial intelligence techniques will be used to model the acquisition of student skills, to select appropriate exercises, to analyze on-going student performance, and to provide appropriate tutorial interventions.

Progress: Implementation of the simulation of parallel analog circuits for the second device implementation of IMTS has been completed. The speed of the fully detailed graphical simulation capability has been improved by a factor of 7, greatly enhancing the interactive instructional quality.

Outside Funding: NPRDC (partial)

TITLE: Intelligent Maintenance Training System

PI: Douglas M. Towne
University of Southern California

(213) 540-3654

R&T PROJECT CODE: pp42001 CONTRACT NO: N0001485C0040

CURRENT END DATE: 28 FEB 1988

Technical Objective: Develop a second application of the Intelligent Maintenance Training System and various improvements to the editor and interface.

Approach: Build second application of IMTS on foundation of first application by modifying and extending on-line configuration editors and simulation driver programs.

Progress: Editors have been completed to configure the system for specific applications. Entry of information for the blade-fold rotor brake application has been completed, and it has been determined that the simulation is successful.

Outside Funding: NPRDC and AFHRL

TITLE: Computation via direct manipulation

PI: Donald A. Norman
University of California
Institute for Cognitive Science
(619) 452-6770

R&T PROJECT CODE: 4006001 CONTRACT NO: N0001485C0133

CURRENT END DATE: 30 NOV 1987

Technical Objective: This research will provide the conceptual foundations for new kinds of human-computer interfaces known as direct-manipulation interfaces. Where conventional interfaces use linguistic expressions to pass information between computers and users, direct-manipulation interfaces use graphic icons to continuously convey the state of computational entities of interest and to permit users to directly manipulate those entities. This research will provide several unique applications of direct-manipulation interfaces (including interfaces to parallel distributed processing systems); and will assess the psychological characteristics of people's use of these interfaces.

Approach: Development tools are created that allow for construction of intelligent graphic icons and system simulations based on these icons. Other development tools help to create direct-manipulation interfaces to systems with many highly-interconnected processors. These tools are used to create particular interfaces to systems such as automatic schedulers and data-base search systems, and the resultant interfaces are evaluated in empirical studies of users' behavior and reactions.

Progress: Software products include the Icon Editor, an interface for a simulation environment; Designer, a knowledge-based graphical design assistant and STATS, a statistical analysis program with a direct manipulation graphical interface. Experiments have been conducted comparing human performance with direct manipulation and command interfaces.

(Note: This project was funded under a special ONR corporate program to encourage collaboration between Navy Laboratories and nearby universities.)

COGNITIVE SCIENCE

CLUSTER 4

MEASUREMENT AND PSYCHOMETRIC THEORY

TITLE: Bayesian techniques for item-response theory.

PI: Robert Tsutakawa
University of Missouri
Department of Statistics
(314) 882-6879

R&T PROJECT CODE: 4421535 CONTRACT NO: N0001485K0113

CURRENT END DATE: 30 SEP 1988

Technical Objective: In item-response theory (IRT) an examinee's item responses are linked to an ability scale through item-response functions (IRF). In the typical IRT application, these IRFs are only partially known through a calibration based on other examinees who have previously taken the same test. The typical application proceeds as if these IRFs were well-estimated; in effect assuming that the calibrations are exact. In previous work Tsutakawa developed techniques for representing uncertainty about the calibrations of these IRFs. In this project that representation is being further checked and is being used to more accurately represent what is known about an examinee's ability. Subsequently, this improved representation of an examinee's ability will be used to better estimate IRFs for new, uncalibrated items.

Approach: This work is employing a combination of theoretical development of the techniques, Monte Carlo simulation to check the performance of the techniques under controlled conditions, and validation with actual response data.

Progress: Research aimed at finding efficient procedures for approximating the marginal posterior distributions of individual ability parameters explored approximations by Leonard, by Tierney and Kadane, and by Lindley. In the general case, none appeared to be practical for routine use. An approach using informative Direchlet priors for the response functions is also under study.

TITLE: Bayesian inference in factor analysis

PI: George Y. Wong
Sloan Kettering Institute
Department of Biostatistics
(212) 794-7546

R&T PROJECT CODE: 4421536 CONTRACT NO: N0001485K0485

CURRENT END DATE: 30 SEP 1989

Technical Objective: This effort is extending previous work on Bayesian approaches to factor analysis. A framework for characterizing the moments of the marginal posterior distributions of the factor loadings, factor scores, and uniqueness variances is being developed; expressions for estimation errors are being derived and compared with those obtained under maximum-likelihood and Bayes-joint-modal approaches; and the sensitivity of the marginal moments to variations in the prior distributions is being examined. In addition these marginal procedures are being extended to the study of oblique factor models, of models with a priori zero factor loadings, and of simultaneous factor models.

Approach: This work is employing a combination of theoretical development of the techniques and Monte Carlo simulation to check the performance of the techniques under controlled conditions. A central element of this research involves approximating the marginal moments of the posterior distributions of factor loadings, factor scores, and uniqueness variances. Techniques based upon an extension of the so-called Tiao-Zellner expansion and refinements of the EM algorithm are being explored.

Progress: Within the framework of the EM algorithm, the E step requires the posterior expectation of the factor loadings and uniqueness variances. Formulas for these expectations have been derived and numerical procedures have been developed to estimate them in practice. In addition, needed approximations for estimating the marginals of a poly-t density have been derived.

TITLE: Modelling conditional dependencies among psychological test items.

PI: Robert D. Gibbons
University of Illinois at Chicago
Department of Psychiatry
(312) 413-1357

R&T PROJECT CODE: 4421538 CONTRACT NO: N0001485K0586

CURRENT END DATE: 30 SEP 1988

Technical Objective: For tractability reasons an assumption of conditional independence has been commonplace in theoretical and practical work in item-response theory. The assumption states that item scores are related to each other only through their relationship with examinee ability. This means that item scores are statistically independent for examinees with the same ability. This work is developing techniques (a) for gauging the extent of conditional dependencies among test items, (b) for obtaining efficient ability estimates in spite of minor dependencies, and (c) for explicitly modelling dependencies in response data.

Approach: The general approach is to model the response patterns without the assumption of conditional independence among test items. To accomplish this investigators are exploring the viability of the so-called Clark algorithm which is based on certain Normality assumptions for approximating pattern probabilities.

Progress: Computational procedures for implementing the Clark algorithm have been developed. In principle these procedures can estimate the probability of any binary response pattern, regardless of test length, item-response-function thresholds, or inter-item dependencies not accounted for by the IRT model. A large-scale Monte Carlo study is currently underway to gauge the adequacy of these procedures.

TITLE: Dimensional Misspecification and Applications of Item-Response Theory

PI: Ming-mei Wang
University of Iowa
Dept of Psychological-Quantitative Foundation
(319) 335-5572

R&T PROJECT CODE: 4421542 CONTRACT NO: N0001486K0031

CURRENT END DATE: 30 SEP 1988

Technical Objective: In the absence of sound theoretical foundations for multidimensional item-response theory, there has been considerable confusion in the literature. Some researchers have equated psychometric dimensions with conceptual dimensions, arguing that a test problem which requires more than one ability (e.g., reading and arithmetic ability) necessarily requires a multidimensional model. Others have called upon the notion of a "complete latent space" to argue that a test model is inappropriately dimensioned if items appear to be conditionally dependent. Still others have called on the more widely understood, yet inappropriate, factor analytic conceptualization for their theorizing. This work will contribute to improving that situation by providing a theoretical framework for addressing dimensionality issues within a broad class of models.

Approach: A mathematical framework for representing the multidimensional situation for a broad class of item-response-theory models is being developed and will be used to anticipate the implications of multidimensionality for model calibration, for adaptive testing, for test bias, and for test equating. In addition improvements to multidimensional modelling and adaptive techniques are being explored.

Progress: (a) An analytical framework based on the linearity of item logit scores for the usual compensatory logistic item response model was defined. (b) Within that framework, algebraic relationships between unidimensional estimates and true multidimensional parameters were derived. (c) Analytical results were demonstrated with simulated data. (d) An index of the dimensionality of the latent space was suggested. (e) Expressions for the bias functions and the mean-square-error of estimate were derived. (f) The implications of unidimensional models for adaptive testing were studied.

TITLE: Foundations of Formula-score Theory

PI: Michael V. Levine
University of Illinois
Department of Educational Psychology
(217) 333-0092

R&T PROJECT CODE: 4421546 CONTRACT NO: N0001486K0482

CURRENT END DATE: 15 JUL 1989

Technical Objective: This work is extending Formula Score Theory (FST) in several ways: First, in its present form FST requires that a unidimensional set of "old test" item-response functions are known exactly a priori. This work is reformulating FST to remove those restrictions. Second, in its present form FST density estimation is adequate only for the limited case in which the density can be represented as a linear combination of a small number of known functions. This work is exploring alternative approaches to density estimation for the more general case. Third, current test equating procedures require that the tests being equated measure the same unidimensional ability. This work is formulating an FST approach for equating multidimensional tests.

Approach: First, procedures based upon initial estimates, followed by iterative cycles (a) of identifying a maximal subset of well-estimated items and (b) of re-estimating other response functions are being explored. Second, a more general FST is being formulated entirely in terms of characteristics of the joint distribution of observables. Third, properties of constrained maximum-likelihood estimators are being examined. Fourth, unidimensional asymptotic theory is being generalized to the multidimensional case. Finally, ability distribution estimation techniques are being extended to the multidimensional case and will be used to describe the equating function between a multidimensional and a unidimensional test.

Progress: (a) An algebraic approach for discovering the shapes of item response functions has been developed which, in principle, can recover non-monotonic response functions, even those with multidimensional support. Although preliminary implementations require very large data sets, refinements are under study. (b) In formula-score theory, item- response functions and densities are characterized by linear combinations of a small number of "basis" functions. An approach for choosing an optimal set of such basis functions has recently been developed.

TITLE: Foundations of Multidimensional Item-response Theory

PI: William F. Stout
University of Illinois at Champaign
Department of Statistics
(217) 333-6218

R&T PROJECT CODE: 4421548 CONTRACT NO: N0001487K0277

CURRENT END DATE: 28 FEB 1990

Technical Objective: This work is further developing the foundations of item-response theory for multidiensional data sets. This includes: (a) exploration of the theoretical relationship between a conditional-association notion of dimensionality and Stout's notion of the essential dimensionality of a data set, (b) exploration of the implications of the Suppes and Zanotti Common Causes Theorem for multidimensional IRT modelling, (c) development of a framework for studying issues of test bias based upon the notion of the essential dimensionality of a test, and (d) exploration of alternative dependence structures for multidimensional modelling.

Approach: (a) Stout's notion of the essential dimensionality of a data set will be refined and extended, and the relationship between it and Holland's notion of conditional association will be derived. (b) The notion of test bias will be cast within the essential dimensionality framework in order to gauge when group differences are likely to be troublesome. (c) New notions of the reliability of a test will be explored. And, (d) Models based upon sequential dependence structures will be examined.

Progress: Developed a generalization of latent-trait theory based entirely on monotonicity and a weak notion of dependence. Results have shown that even with this weaker notion of dependence, latent-trait theory retains many of its important measurement properties.

TITLE: Latent-trait theory for polychotomously-scored items

PI: Fumiko Samejima
The University of Tennessee
Department of Psychology
(615) 974-6846

R&T PROJECT CODE: 4421549 CONTRACT NO: N0001487K0320

CURRENT END DATE: 28 FEB 1990

Technical Objective: The objective of this work is to develop the theoretical foundations for polychotomously-scored test items with non-monotone item-response functions. Included are (a) improvements to modelling techniques, (b) exploration of criteria for response characteristics of items in an ideal item pool, for efficient item selection, and for test termination, (c) development of procedures for describing examinee performance, (d) development of procedures for calibrating items online, and (e) development of a framework for assessing item and test validity within an item-response-theory framework.

Approach: (a) The PI's procedures for non-parametric estimation of item-response functions will be extended to the case in which the latent density is badly skewed and to the case in which it is multidimensional. (b) The usefulness of approximations derived from results for multidimensional models of continuous responses will be examined. (c) A variety of ways to conceptualize an item's local validity will be studied. And, (d) results will be implemented in portable computer programs.

Progress: The conditional PDF approach for estimating the operating characteristics has been developed. A critical step in the method involves an approximation to the conditional distribution of the maximum-likelihood ability estimates given ability. Studies with a variety of empirical data sets indicate that the standard approximation may be seriously biased for extreme abilities. To help understand the extent of this problem for particular item sets, an approximation to the bias function has been derived and examined.

TITLE: Discrete-state item-response models

PI: James A. Paulson
Portland State University
Department of Psychology
(503) 229-3923

R&T PROJECT CODE: 4421550 CONTRACT NO: N0001487K0280

CURRENT END DATE: 30 APR 1990

Technical Objective: This work is examining new approaches for estimating and validating latent-class models. In previous work, the investigator made effective use of the EM algorithm to estimate these models in unconstrained and in a variety of constrained situations. In this work, he will develop a framework for incorporating a monotonicity constraint when appropriate.

Approach: (a) A test statistic for monotonicity will be developed, and its sampling distribution will be studied. (b) Alternatives to monotonicity will be explored for those situations in which it fails. An approach to be examined early on would add additional states to the model. Partially-ordered hierarchical models will also be examined. (c) Links between these discrete-state models and widely-studied continuous-state models will be examined. In particular, this approach will be compared to the Bock and Aitken approach.

Progress: Procedures have been developed for diagnostic classification during training within the general framework of latent-class analysis. Efficient computational algorithms have been designed. Studies underway are examining the robustness of classifications to model misspecification.

TITLE: Latent-trait representations of behavioral data

PI: Paul W. Holland
Educational Testing Service
Statistical & Psychometric Research Div.
(609) 921-9000

R&T PROJECT CODE: 4421551 CONTRACT NO: N0001487K0730

CURRENT END DATE: 31 JUL 1990

Technical Objective: One way to view the central problem of item-response theory is the discovery of a parsimonious representation of behavior which reproduces the important features of a data set. The investigator has discovered an identity which appears to linearize that problem for a very general class of models. This project is exploring the ramifications of that identity for item-response theory.

Approach: Numerical studies will examine the viability of representations derived from the Dutch identity in practice. The issue of how large tests must be before first-order approximations are viable will be studied, and the implications of second-order approximations for IRT modelling will be examined.

Progress: Preliminary work is examining how test models behave with large numbers of items, the identifiability of parameters, and new ways to assess dimensionality in item-response-theory models. Results include a demonstration that if the test has dimension D and has length J, at most (D+1)J parameters can be estimated.

TITLE: Dealing with uncertainty in item-response theory.

PI: Robert J. Mislevy
Educational Testing Service
Statistical and Psychometric Research Div.
(609) 734-1271

R&T PROJECT CODE: 4421552 CONTRACT NO: N0001488K0304

CURRENT END DATE: 31 MAR 1990

Technical Objective: The work will involve three main tasks: (a) Statistical theory and approximation and computing techniques will be developed for a fully Bayesian approach to item response theory including techniques for obtaining marginal distributions for examinee abilities and item parameters. (b) Difficulties with hyper-variances in hierarchical Bayesian models will be studied. And, (c) theory for drawing inferences from behavior samples within examinees will be developed.

Approach: First, since conjugate priors are not available for IRT applications, investigators will explore a variety of approximations including those proposed by Dunsmore, by Leonard, by Lindley, by Rubin, and by Tierney and Kadane. Second, since data provides virtually no information on hyper-variances and since non-informative priors on hyper-variances are troublesome, investigators will study the influence of moderate priors on posterior results. Finally, investigators will extend their earlier work on drawing inferences from item samples.

Progress: This contract is new in FY1988.

TITLE: Multidimensional item-response theory for training applications

PI: Mark D. Reckase
American College Testing Program

(319) 337-1105

R&T PROJECT CODE: 4422531 CONTRACT NO: N0001485C0241

CURRENT END DATE: 31 AUG 1988

Technical Objective: This work is developing useable item-response theory for training applications. Work is exploring the adequacy of compensatory models for characterizing typical training performance; techniques for increasing the accuracy and efficiency of item response function estimation algorithms (especially in small samples); the extension of the unidimensional notions of item difficulty, discrimination, and information to a general class of multidimensional models; the implications of adaptive testing for the complexity of the content dimensions being assessed; the effectiveness of appropriateness indices for detecting items whose characteristics have changed since the response models were originally calibrated; and, the nature of and effective methods for dealing with the trade off between test efficiency and test security in applications.

Approach: This work is employing a combination of theoretical development of the techniques, Monte Carlo simulation to check the performance of the techniques under controlled conditions, and validation with actual response data.

Progress: First, the notions of item difficulty, discrimination, and item information for an item which measures more than one dimension have been formulated. Second, a detailed study of how multidimensional difficulty and discrimination can be used to form item sets which operate as if they were unidimensional has been conducted. The hypothesis was that a set of items which have their highest discrimination in roughly the same direction will operate as if it were unidimensional. Analyses of data from a mathematics usage test generally supported this hypothesis, although some small item sets which were fairly difficult were problematic.

TITLE: A theory of IRT-based diagnostic testing

PI: Kikumi K. Tatsuoka
University of Illinois
Computer-based Education Research Lab.
(217) 333-6700

R&T PROJECT CODE: 4422541 CONTRACT NO: N0001486K0290

CURRENT END DATE: 14 APR 1989

Technical Objective: The objective of this work is the further development of the foundations of the rule-space framework for diagnosing the misconceptions of trainees from their performance on cognitive tasks.

Approach: (a) Develop a coherent mathematical/statistical theory for rule space inferences, (b) establish convergence and efficiency properties of adaptive item-selection strategies, (c) refine approximations to the so-called "bug distribution", (d) extend the model to deal with polychotomously-scored responses, and (e) investigate the generality of the framework within a Navy training context.

Progress: Recent analytical results established the algebraic relationships between certain item-response-theory models, latent-class models, and rule-space models. Specifically, it was shown (a) that IRT functions may be regarded as the conditional density functions of item scores for a special latent class representing the "null state of knowledge" (i.e., the state which would ideally produce all incorrect responses); and (b) that estimates of the item parameters of IRT functions can be determined from the union of several latent classes with the property: when their response vectors are mapped into rule space, their projections lie approximately along the first principle axis of the union set.

PERCEPTUAL SCIENCE

CLUSTER 5

VISION

TITLE: Integrating Spatial Information

PI: Kent A. Stevens
University of Oregon
Department of Computer Science
(503) 686-4430

R&T PROJECT CODE: 4424206 CONTRACT NO: N0001487K0321

CURRENT END DATE: 14 MAY 1990

Technical Objective: Objective is to develop a theory of 3-D form perception based on an assumption of two independent representation systems for distance information: one for absolute distance and another for local object-referenced depth relations.

Approach: Approach is a combination of theoretical analysis, computational modeling and psychophysical experimentation. Specific hypotheses to be developed and tested are that apparent slant of a geometric figure induces a depth inference; that apparent slant of a surface induces size constancy, and that multiple cues are not converted to a common metric and summed but are treated as evidence in a Bayesian estimation sense.

Progress: Apparent depth in stereograms exhibits various simultaneous-contrast effects analogous to those reported in the luminance domain. This behavior suggests that stereo depth, like brightness, is reconstructed from first or higher-order derivatives. The investigator has examined the extent to which depth is analogous to brightness, and found similarities in terms of contrast effects but dissimilarities in terms of lateral-inhibition effects traditionally attributed to the underlying spatial-derivative detection operators. Brightness effects such as Mach bands that are attributed to spatial lateral inhibition are not found in stereo depth.

TITLE: Inferring 3-D Shape from Motion and Occluding Contours

PI: Donald D. Hoffman
University of California, Irvine
Department of Cognitive Science
(714) 856-6795

R&T PROJECT CODE: 4424194 CONTRACT NO: N0001485K0529

CURRENT END DATE: 30 JUN 1988

Technical Objective: Objective is to develop computational theories for human visual processes; test and extend them by means of psychophysical experiments with human subjects. Visual processes of interest are those which integrate mutual constraints on shape derived from image motion and occluding contours.

Approach: Approach is a multidisciplinary interplay between mathematical modeling and psychophysical experimentation. Experiments both test psychological validity of current models and suggest new, psychological constraints in addition to physical constraints in resolving ambiguity in inferring shape from image motion and occluding contours.

Progress: Psychophysical experiments were conducted to test predictions of structure-from-motion algorithms regarding human abilities to perceive depth under a variety of 2-D stimulus conditions. The stimuli were combinations of numbers of points, numbers of distinct views and kinds of motion constraints imposed. Theoretical analysis suggested minimum requirements of three views of two points. Experimental results suggest humans have the ability to recover depth given two views of two points. Exploration of additional motion constraints that might be used by subjects to infer shape form motion are being carried out.

TITLE: INFERRING 3-D SHAPE FROM MOTION AND CONTOURS

PI: Donald D. Hoffman
The Regents of the University of California
School of Social Sciences
(717) 856-6802

R&T PROJECT CODE: 400d122 CONTRACT NO: N0001487G0135

CURRENT END DATE: 14 MAR 1988

Technical Objective: This effort is for the purchase of equipment under the DOD-University Research Instrumentation Program. The goal of this program is to improve the capability of universities to perform research in support of national defense. This program of support for the acquisition of research equipment has the primary purpose of stimulating and supporting basic research underlying the technology goals of the Department of Defense.

Approach: The equipment includes: Symbolics Lisp Machine and a Microvax Workstation. This instrumentation will support research on computational studies and psychophysical experiments dealing with the recovery of 3-D shape from image motion and occluding contours.

Progress: The equipment described above has been purchased and is being used to support new vision research.

TITLE: Formal and Psychophysical Investigations of Vision: Image Motion and Occluding Contours

PI: Donald D. Hoffman
University of California, Irvine
Department of Cognitive Sciences
(714) 856-6795

R&T PROJECT CODE: 4424219 CONTRACT NO: N0001488K0354

CURRENT END DATE: 31 MAY 1991

Technical Objective: The objective of the proposed research is to develop and to evaluate both empirically and computationally a formal theory of the mechanisms by which object shape can be inferred from motion and contour occlusion. An additional objective is to implement this theory in neurally plausible computer algorithms.

Approach: The proposed investigation will consist of three integrated thrusts: (1) the development of formal theories of shape-from- motion and shape from occluding contours, (2) the testing of these theories by psychophysical experiments, and (3) the implementation of these theories in neurally plausible computer algorithms.

Progress: This contract is new in FY1988.

TITLE: Vision Research Using Cellular Automata

PI: Donald A. Glaser
The Regents of the University of California, Berkeley
Molecular Biology
(415) 642-7231

R&T PROJECT CODE: 4425089 CONTRACT NO: N0001485K0692

CURRENT END DATE: 31 JUL 1988

Technical Objective: Objective is to explore hierarchical, asynchronous cellular automata as processor models for the human visual system.

Approach: The approach is to design alternative automata structures and operating rules capable of transforming visual images in ways that enable visual tasks to be performed and to test alternative models for psychological validity via psychophysical experiments.

Progress: Using the formalism of cellular automata and parallel processing networks, computational models are being developed of human binocular stereo depth perception, of motion perception, and of the ability to judge symmetry. In experiments of depth perception, the investigators have found that the apparent depth of a dot depends on the disparities of these items plus some effect due to disparities of other objects in the field of view. The human visual system is therefore unlike a conventional stereoscopic camera in which the depth of any object can be determined exactly by measuring the position of its images on the two views. In experiments on perception of apparent motion, they have found that in ambiguous situations the human visual system perceives vertical motion more often than horizontal motion. A theory based on neural-anatomical factors has been formulated to explain the latter finding.

TITLE: RESEARCH ON HUMAN VISION USING CELLULAR AUTOMATA

PI: Donald A. Glaser
The Regents of the University of California
Molecular Biology
(415) 642-7231

R&T PROJECT CODE: 400d104 CONTRACT NO: N0001487G0109

CURRENT END DATE: 31 JAN 1988

Technical Objective: This effort is for the purchase of equipment under the DOD-University Research Instrumentation Program. The goal of of this program is to improve the capability of universities to perform research in support of national defense. This program of support for the acquisition of research equipment has the primary purpose of stimulation and support of basic research underlying the technology goals of the Department of Defense.

Approach: The equipment includes: Pritchard SpectraRadiometer, Gerbrands Techistoscope with Mast random access slide projectors, CCD television camera and Jupiter Systems J Station image processor. Human visual performance will be investigated in terms of underlying computational processes carried out in the brain. Theories will be formulated to connect psychophysical measurements of visual performance with known structures in the neuroanatomy of the visual system.

Progress: The equipment described above has been purchased and is being used to support new vision research.

TITLE: Computation of Visual Form

PI: Tomaso A. Poggio
Massachusetts Institute of Technology
Center for Biological Information Processing
(617) 253-5230

R&T PROJECT CODE: 4007005 CONTRACT NO: N0001485C0038

CURRENT END DATE: 31 DEC 1987

Technical Objective: To bring together new theoretical and computational developments, experimentation in visual psychophysics, and studies of physiological mechanisms underlying binocular stereo, visual motion, and their fusion within the visual system.

Approach: To combine psychophysical and physiological analyses to develop the empirical basis for a computational treatment of binocular stereo, visual motion, and their fusion within the visual system.

Progress: The investigators have demonstrated that a color algorithm capable of separating illumination from reflectance in a multi-surface space can be learned from a set of examples. The learned algorithm is equivalent to filtering the image data through a center-surround receptive field in individual chromatic channels. This result is a specific instance of an earlier result that a standard regularization algorithm can be learned from examples. The learning procedure has been implemented as parallel algorithm on the Connection Machine System.

TITLE: COMPUTATION OF VISUAL FORM

PI: Tomaso Poggio
Massachusetts Institute Technology
Center for Biological Information Processing
(617) 253-0551

R&T PROJECT CODE: 400d080 CONTRACT NO: N0001486G0152

CURRENT END DATE: 31 JUL 1988

Technical Objective: This effort is for the purchase of equipment under the DoD-University Research Instrumentation Program. The goal of this program is to improve the capability of universities to perform research in support of national defense. This program of support for the acquisition of research equipment has the primary purpose of stimulation and support of basic research underlying the technology goals of the Department of Defense.

Approach: Equipment includes two Symbolics Lisp Machines, frame buffer, color monitors and scientific instrumentation for an electrophysiology laboratory. This equipment will support theoretical and computational studies, experimentation in visual psychophysics, investigations of biophysical mechanisms underlying information processing in neural hardware and experimentation in electrophysiology.

Progress: The equipment described above has been purchased and is being used to support new vision research.

TITLE: Visual Integration and Recognition

PI: Tomaso A. Poggio
Massachusetts Institute of Technology
Center for Biological Information Processing
(617) 253-5230

R&T PROJECT CODE: 442g002 CONTRACT NO: N0001488K0164

CURRENT END DATE: 31 DEC 1990

Technical Objective: Objective is to specify biologically plausible implementation models for visual integration and recognition.

Approach: Approach is a combination of computational modeling, human psychophysics and animal neurophysiology. Visual integration is modeled as coupled Markov Random Fields. As yet, no unifying formal model exists for recognition, but a 3-stage process involving segmentation, indexing, and verification will be explored.

Progress: This contract is new in FY1988.

TITLE: Neural Models of the Visual Cortex in Information Processing

PI: David C. Van Essen
California Institute of Technology

(818) 356-6823

R&T PROJECT CODE: 4425083 CONTRACT NO: N0001485K0068

CURRENT END DATE: 30 NOV 1988

Technical Objective: Objective is to develop for use with lower mammals and primates an optical monitoring technique for studying interactions among clusters of cortical neurons in response to features of visual stimuli.

Approach: Approach is to adapt techniques previously developed for simple invertebrate nervous systems for use with higher order organisms, then to conduct experiments varying selected features of visual stimuli presented via an integrated raster imaging system.

Progress: Van Essen and Anderson have developed a novel hypothesis concerning an information routing strategy for dynamic control of flow between arrays of neurons at different levels of the visual pathway. They propose a specific type of neural circuitry, called a "Shifter Circuit" which allows for dynamic shifts in relative alignment of input and output arrays that maintain information from the two retinas in register without loss of local spatial relationships. The hypothesis is consistent with available anatomical and physiological evidence on the organization of the primate visual pathway. It will be tested in psychophysical experiments of motion and depth perception.

TITLE: Processing Information in the Cerebral Cortex

PI: John H. Maunsell
University of Rochester
Strong School of Medicine and Dentistry
(716) 275-2076

R&T PROJECT CODE: 400x013 CONTRACT NO: N0001486K0646

CURRENT END DATE: 31 JUL 1988

Technical Objective: The objectives are to identify neural networks in macaque visual cortex which store symbolic information required for object recognition and to trace pathways through which memorial and sensory sources are combined. Results are expected to generate hypothesis concerning human visual processes.

Approach: Approach is to train macaque monkeys in both tactile and visual form discrimination, then perform match-to-sample experiments while recording neural activity in several cortical areas.

Progress: Recently completed experiments have confirmed the existence of significant numbers of neurons in area V4 of macaque visual cortex that encode task-dependent information. These results indicate that previous conceptions of area V4 as only a sensory processing area are incorrect. One hundred sixty six neurons in V4 were found to become active in a match-to-sample task in a manner suggesting that these neurons were storing the original stimulus configuration being searched for in the task.

TITLE: Analog Neuronal Networks for Early Vision

PI: Christof Koch
California Institute of Technology
Computation and Neural Systems
(818) 356-6855

R&T PROJECT CODE: 400x038 CONTRACT NO: N0001487K0519

CURRENT END DATE: 30 JUN 1990

Technical Objective: Objective is to develop theoretical models of computation for early visual processes.

Approach: The approach is to simulate analog algorithms for vision on a hypercube computer in two stages; first as independent, then as integrated processes;and to explore design possibilities for silicon implementation.

Progress: Koch has developed a computer simulation of the neural circuitry by which the visual system of cat analyzes motion. The model includes processes performed by neurons in the retina, lateral geniculate nucleus and cortical area 17. The model incorporates details of neuronal receptive field properties and is implemented on a SUN-3 workstation.

TITLE: Using Time-to-Collision to Recover 3-D Motion for Navigation and Manipulation

PI: Ellen Hildreth
Massachusetts Institute of Technology
Office of Sponsored Programs
(617) 253-1441

R&T PROJECT CODE: 400x052 CONTRACT NO: Not yet assigned

CURRENT END DATE: 30 JUN 1991

Technical Objective: To establish the computational and psychophysical bases for design of networks that have the capacity to compute quickly and accurately the structure and relative motions of environmental objects with which an artificial system may physically interact during the course of navigation and object manipulation.

Approach: Estimates of the time-to-collision with an approaching surface will be used to investigate the recovery of 3-D trajectory of moving targets. The psychophysical findings will be employed as the basis for design of computational models of visually- guided navigation and object manipulation.

Progress: This contract is new in FY1988.

TITLE: Tests of a Multilevel Computational Theory of Stereoscopic Visual Image Processing

PI: William R. Uttal
Naval Ocean Systems Center
Marine Science/Tech Dept
(808) 254-4343

R&T PROJECT CODE: 4425084 CONTRACT NO: N0001487WX24063

CURRENT END DATE: 31 DEC 1987

Technical Objective: To develop and test a computational model of human visual detection, discrimination, recognition and reconstruction, with particular concern for the role of local versus global processing factors.

Approach: This project is a mix of two approaches. First it is necessary to carry out psychophysical experiments to determine how human observers detect, discriminate between, recognize and reconstruct three-dimensional objects formed from arrays of dots and embedded in a surrounding of randomly positioned dots. These data are then used as suggestive heuristics to develop a formal computational model of the process. The model is then used both as a theory that can predict human performance and as a prototype of a computer-vision machine capable of carrying out the same tasks automatically. The psychophysical experiments are carried out in a computer-controlled environment in which solid appearing objects are generated by a stereoscopic process. The model is developed on a graphics work station.

Progress: Results from an extensive set of empirical studies investigating the attributes of 3-D forms that affect their perception during discrimination, recognition, and reconstruction have been reported in a book length monograph.

TITLE: Synoptic and taxonomic analysis of form perception data and theory

PI: William R. Uttal
Naval Ocean Systems Center Detachment
Marine Sciences/Technology Department
(808) 254-4434

R&T PROJECT CODE: 4425091 CONTRACT NO: N0001487WX24214

CURRENT END DATE: 31 DEC 1987

Technical Objective: To review and analyze the available literature in the field of visual form-perception and to write a monograph summarizing the current state of the field.

Approach: A synoptic review is made of the literature on peripheral and central visual physiology and from the pre-attentive to the attentive/ cognitive points of view. The special goal is to link those points of view into an integrative theory of visual form-perception.

Progress: Final drafts of 5 chapters have been completed that include: (a) Introduction and perspective to the monograph; (b) Theories of form perception; (c) Detection of visual forms; (d) Discrimination of visual forms; and (e) Recognition of visual forms. These chapters have undergone several revisions. Plans have been made for external review of these chapters and the subsequent publication of this work by a commercial firm on a non-royalty basis.

Outside Funding: AFOSR

TITLE: Computational Analysis of 3-D Form from Shading and Texture

PI: Dr. James T. Todd
Brandeis University
Psychology
(617) 647-2954

R&T PROJECT CODE: 4425088 CONTRACT NO: N0001485F0135

CURRENT END DATE: 30 JUN 1988

Technical Objective: Objective is to provide a data base of psychophysical functions between stimulus variables and perceptual judgments as foundations for the computational analysis of human vision.

Approach: Approach is to develop a library of stimulus materials that include interactions of several variables: texture, shape, size and distribution, shading, reflectance and illumination; then to conduct psychophysical experiments that relate stimulus variations to judgments of orientation, depth and Gaussian curvature.

Progress: A series of experiments were conducted to investigate relationships between patterns of optical texture and the perceived shape of curved surfaces. In general, contour lines are stronger cues to surface shape than texture patterns, but small variations in texture pattern can make very large differences in accuracy of perceptions in 3-D. For example curved surfaces generated by identical rules for size, compression and density gradients were viewed more accurately when elongated rectangles in alignment were compared to texture composed of unaligned squares.

Outside Funding: NSF

TITLE: Image Restoration

PI: Robert Hummel
New York University
Courant Institute of Mathematics
(212) 460-7364

R&T PROJECT CODE: 4007006 CONTRACT NO: N0001485K0077

CURRENT END DATE: 31 JAN 1989

Technical Objective: Develop a theory of image data structures for human vision based on variations of the Laplacian pyramid as an image representation scheme. Study methods for labeling information in image representations which emphasize combining evidence from multiple data sources to achieve a consensus-based label (inference).

Approach: The Laplacian pyramid and its variants will be explored as a plausible representation scheme for human vision. Relaxation labeling methods will be explored as a theory of information extraction and tested in psychophysical experiments.

Progress: During the past performance period, four technical reports have been written. Progress on the theory of evidence and models of methods for the combination of information when dependencies in the knowledge sources make independence assumptions unrealistic was made. New algorithms were developed in the area of matching model-based vision using boundary tracking and other feature-extracting methods.

PERCEPTUAL SCIENCE

CLUSTER 6

ATTENTION

TITLE: Structure and function of an attentional system

PI: Michael I. Posner
Washington University
Anatomy Department
(314) 362-3317

R&T PROJECT CODE: 442a554 CONTRACT NO: N0001486K0289

CURRENT END DATE: 30 APR 1989

Technical Objective: The objective is to develop a better understanding of the role of attention in the execution of a wide variety of cognitive skills and a way of specifying the consequences of deficits in various parts of the neural machinery underlying attentional performance.

Approach: The major methodologies to be employed to identify the function and neuroanatomical loci of the elementary operations underlying attentional behavior include (1) performance studies of normal persons, (2) the use of selected neurological cases with specified lesions in brain areas believed to perform the computations underlying attention, (3) measurement of event-related potentials produced in normal persons and neurological patients engaged in attentional tasks, and (4) studies of cerebral blood flow in normals and patients engaged in attentional tasks.

Progress: Interactions among posterior parietal cortex, pulvinar, and superior colliculus in determining the dynamics of visual-spatial attention were evidenced through studies of neurological patients. In addition, evidence was obtained indicating that lexical access for familiar words occurs without the need for attentional processing. The latter finding was based on data from both normals and brain-damaged patients.

TITLE: Attention in the Visual Field

PI: David La Berge
University of California, Irvine
Department of Cognitive Sciences
(714) 856-6802

R&T PROJECT CODE: 4424208 CONTRACT NO: N0001488K0088

CURRENT END DATE: 31 JAN 1989

Technical Objective: The objective is to test and elaborate the PI's gradient theory of visual-spatial attention. Evaluation of the theory will be based on empirical research and computer simulation.

Approach: An extensive series of experiments will be carried out to analyze the 'width of attentional focus' effect, on which the PI's theory of attention is based, to explore methods to produce and sustain an attentional gradient of a given extent, and to determine ways in which the focus-width effect can be exploited to optimize human performance in tasks involving object recognition.

Progress: This contract is new in FY1988.

TITLE: A rodent model to identify brain structures involved in the process of stimulus recognition

PI: Lawrence A. Rothblat
George Washington University
Psychology Department
(202) 994-6809

R&T PROJECT CODE: 4424210 CONTRACT NO: N0001488K0227

CURRENT END DATE: 31 JAN 1991

Technical Objective: The objective is to develop a rodent model system for investigation of the role of limbic system structures, including the hippocampus, the amygdala, and the rhinal cortical structures, in memory for, and recognition of visual objects and their spatial locations.

Approach: Lesion and tracer techniques will be used to examine the role in stimulus recognition of a variety of limbic system structures, including the hippocampus, amygdala, and rhinal cortex. The effects of controlled lesions will be assessed behaviorally and verified histologically.

Progress: This contract is new in FY1988.

TITLE: Spatial visual attention

PI: Ronald J. Tusa
Johns Hopkins University
Neurology
(301) 955-1229

R&T PROJECT CODE: 4424211 CONTRACT NO: N0001488K0280

CURRENT END DATE: 30 JUN 1990

Technical Objective: To elucidate the role of the posterior parietal cortex in controlling and maintaining the focus of visual/spatial attention, and specifically to determine whether visual attention is craniotopic or somatotopic and whether it has a directional or a representational organization.

Approach: Rhesus monkeys and human patients with cortical, sub-cortical lesions and collosal sections will be studied in a variety of attentional tasks requiring the subject to focus attention in either the contra- or ipsi-lesional visual field. The effects of various lesions will be determined both physiologically and behaviorally.

Progress: This contract is new in FY1988.

TITLE: Physiology of selective attention

PI: Harold E. Paschler
University of California, La Jolla
Psychology
(619) 534-3974

R&T PROJECT CODE: 4424212 CONTRACT NO: N0001488K0281

CURRENT END DATE: 31 JAN 1991

Technical Objective: The objectives are to better characterize the mechanisms whereby primates selectively attend to stimuli that are relevant, while ignoring irrelevant stimuli.

Approach: Both human subjects and macaque monkeys will be studied under similar task conditions. Psychophysical measures will be obtained from both subject types, and carefully controlled physiological measures of attention-related neural activity in cortical and sub-cortical structures will be obtained in the monkeys.

Progress: This contract is new in FY1988.

TITLE: Visual attention and short term memory

PI: George Sperling
New York University
Psychology
(212) 998-7868

R&T PROJECT CODE: 4424221 CONTRACT NO: Not yet assigned

CURRENT END DATE: 31 MAY 1991

Technical Objective: The objective of the proposed project is to develop formal quantitative descriptions of the mechanisms by which attentional modulation and control structures determine the perception of visual events, and to incorporate these descriptions into a theoretical treatment of human information processing and the sources of its limitations.

Approach: The proposed project incorporates both psychophysical and computational analyses to generate the empirical basis for and computational evaluation of a formal theory of the role of attention in the analysis of visual input.

Progress: This contract is new in FY1988.

TITLE: Electrophysiological Studies of Visual Selective Attention and Resource Allocation

PI: Steven A. Hillyard
University of California
Neurosciences
(619) 452-3797

R&T PROJECT CODE: 4426556 CONTRACT NO: N0001486K0291

CURRENT END DATE: 31 MAY 1989

Technical Objective: The specific objectives of the work are (1) to validate the visual event-related potential (VERP) as an index of selective attention and perceptual acuity; (2) to study the spatial distribution of attention within a large stimulus array during conditions of focussed and divided attention; (3) to evaluate the use of VERPs to probe stimuli as indices of attentional allocations and workload; and (4) to study the effect of background structure on the focussing of attention.

Approach: The methodology will be based on the use of the visual event-related potential, a sensitive indicator of the deployment of selective attention to stimulus events at different spatial locations. The distribution of attention over a stimulus array will be studied as a function of the type of stimulus material, the task assignment, the difficulty of the task, and the structure of the stimulus field.

Progress: Several theoretically important experiments have been completed. This work indicates that (1) the locus of attentional facilitation in visual information processing first appears in the prestriate cortex, (2) facilitation based on spatial cueing occurs prior to that based on cueing of target features such as color or shape, and (3) human subjects distribute attention through visual space according to the relative probabilities of target occurrence at various sites (i.e., they probability-match).

TITLE: Role of Locus Coeruleus Activity in Regulation of Behavioral Responsiveness

PI: Gary Aston-Jones
New York University
Biology
(212) 598-3994

R&T PROJECT CODE: 4426559 CONTRACT NO: N0001486K0493

CURRENT END DATE: 31 AUG 1989

Technical Objective: This research is intended to determine the residual stress distribution at carbide inclusions as a function of carbide morphology, using X-ray diffraction methods and analytical modeling. In particular, the influence of fatigue loading, both to impart residual stress and to alleviate residual stress, will be emphasized.

Approach: Residual stresses in metals can be characterized by their effects on diffraction peaks and their diffraction constants. The magnitude and sign of macrostresses and microstresses in a steel containing carbide particles in a ferrite matrix will be determined using X-ray and neutron diffraction techniques. The microstructure of the steel will be varied to include three different carbide particle morphologies. Effects of fatigue loading to cause residual stresses will be modeled and will be experimentally determined.

Progress: Experiments have established that the locus coeruleus receives projections from the superior colliculus, and in turn projects to the pulvinar, posterior parietal cortex, and back to the superior colliculus. Since all these structures have been shown to be involved in attentional processing, these findings provide further support for the idea that the nucleus in intimately involved in attentional processing.

Outside Funding: AFOSR (partial)

PERCEPTUAL SCIENCE

CLUSTER 7

AUDITION

TITLE: Recognition of Isolated Non-Speech Sounds

PI: James A. Ballas
Georgetown University
Department of Psychology
(202) 625-3453

R&T PROJECT CODE: 4424199 CONTRACT NO: N0001486K0243

CURRENT END DATE: 28 FEB 1989

Technical Objective: To establish the mediation processes that underlie the recognition of isolated sounds, and the perception of multiple sounds, as single acoustic sequences, and to define those processes in terms of information-theoretic measures. The results of those studies will be important to other investigators who are interested in the development of strong model of auditory classification for incorporation into a military system for recognition of non-speech acoustic transients.

Approach: Experiments are continued on the identification of the acoustic event that causes a particular sound to be generated and the measurement of the uncertainty of that identification. A new method is evaluated for the assessment of the listener's judgments of the alternate causes of acoustic sequences, the effectiveness of anchoring judgments, and the specification of the range of uncertainty about the causes.

Progress: An information-theoretic measure of the recognizability of isolated-sound sequences was developed, verified, and validated. Three experiments were completed that specify the role of the number of alternate acoustic events, quantity the number of probable acoustic sources, and identify the perceptual-cognitive processes that mediate the effects of multiple acoustic events.

TITLE: Recognition of Environmental Sound

PI: James A. Ballas
George Mason University
Center for Behavioral Studies
(703) 323-2059

R&T PROJECT CODE: 4424205 CONTRACT NO: N0001487K0167

CURRENT END DATE: 28 FEB 1989

Technical Objective: To establish the mediation processes that underlie the recognition of isolated sounds and the perception of multiple sounds, as single acoustic sequences, and to define those processes in terms of information-theoretic measures. The results of those studies will be important to other investigators, who are interested in the development of a strong model of auditory classification for incorporation into a military system for the recognition of non-speech acoustic transients.

Approach: Experiments are conducted on the identification of the acoustic event that causes a particular sound to be generated and the measurement of the uncertainty of that identification. Techniques are developed to measure the encoding processes, and their operational sequence, for the recognition of environmental sounds.

Progress: Research equipments and experimental facilities were assembled for the conduct of research programs. Staffing of research team with graduate students was completed. Research procedures were exercised and calibrated for the initiation of research programs.

TITLE: Principles of Perception in the Sonar of Bats

PI: James A. Simmons
Brown University
Department of Psychology
(401) 863-1542

R&T PROJECT CODE: 4424202 CONTRACT NO: N0001486K0401

CURRENT END DATE: 30 JUN 1989

Technical Objective: To study the neural processing of acoustic signals by bats for the recognition of targets that are detected by echo-location, analyzed in real-time with highly-parallel processing strategies, and displayed on the organism's cortex after neural computations are performed by distributed processing elements.

Approach: Experiments are conducted to ascertain the target-range map in the auditory cortex of the bat and to identify the parameters of the neural response patterns that can be read from that neural map. Relationships are developed between the map data and behavioral measures collected of range acuity and the size of the zone of clutter interference along the range axis.

Progress: Experiments were completed that replicated prior results which determined that bats can detect very small changes in distance to a target (0.2 mm) from the time delays. The return echoes consist of multiple echoes spaced over an interval of 100-200 microseconds. These echoes are summed together by the bat to form a representation of the time-intervals separating the echo components in terms of the spectrum of the whole compound echo from the target.

TITLE: Contextual encoding of acoustic transients

PI: Thomas E. Hanna
Naval Submarine Base, New London
Auditory & Communication Sciences Department
(203) 449-2561

R&T PROJECT CODE: 4424207 CONTRACT NO: N0001488WR24003

CURRENT END DATE: 31 DEC 88

Technical Objective: To test theories of trace and context encoding in the classification of acoustic transients that arise from either active or passive sound sources. To assess the salient dimensions of synthesized transient sounds, their natural boundaries, the interdependence of spectral and temporal shape, and the identification of psychophysical dimensions, for classification performance.

Approach: Transient sounds are synthesized with variations in the dimensions of spectral shape, temporal envelope, and spectral distribution, but at constant levels of loudness. Classification performance is determined with variable inter-signal intervals in order to test predictions from encoding theories. Predictions of classification performance are tested further with signals from active and passive sound sources taken from the ASW environment; and the robustness of the theories is extended to include broader ranges of signal types.

Progress: Synthetic acoustic transients were developed from tonal complexes and bands of noise. Experiments were conducted that manipulated the rate of temporal modulation of those transients to assess the ability of users to discriminate and identify those signals. Underwater sounds were collected and decomposed to extract their temporal dimensions; representative sound types of those dimensions were selected for subsequent psychophysical analysis.

TITLE: Auditory Profile Analysis By Parallel Associative Networks

PI: James H. Howard, Jr.
Catholic University of America
Department of Psychology
(202) 635-5748

R&T PROJECT CODE: 4424213 CONTRACT NO: N0001488K0261

CURRENT END DATE: 31 JAN 1991

Technical Objective: To extend the understanding of the profile analysis model of acoustic discrimination by developing a neural net model of the same acoustic phenomena. To test the neural net model for its discrimination of transient, multitonal signals in order to identify and quantitatively express the algorithms used for the processing of those signals, and to determine the algorithms for the classification of those sounds.

Approach: Neural net models are developed which discriminate intensity changes in transient, multitonal signals which vary in (a) the number and spatial density of their components; (b) loudness level and its variability; and (c) frequency range. Learning characteristics of the neural network under different profile conditions are assessed. Structural parameters of the neural network are varied to determine the conditions that optimize the learning performance of the networks.

Progress: This contract is new in FY1988.

TITLE: Panel on Classification of Complex, Non-speech sounds

PI: Milton A. Whitcomb
National Academy of Sciences
National Research Council
(202) 334-2300

R&T PROJECT CODE: 4424204 CONTRACT NO: N0001487C0272

CURRENT END DATE: 30 SEP 1988

Technical Objective: To review the current literature on complex sound processing by the auditory system in order to understand the status of the field, identify the more important areas of research, and assess laboratory activity engaged in research on auditory classification. Visits will be made to Navy laboratories in order to integrate findings into a better under- standing for ASW operations relative to signal classification by machine and human operators.

Approach: An expert Panel is assembled in relevant areas to auditory system processing. The Panel will meet at least 3 times, conduct surveys of laboratories in the US and abroad working in the problem area, visit US Navy laboratories for information on current and anticipated research needs, and prepare an evaluative report on their findings.

Progress: An expert panel reviewed the current research literature on auditory perception of target classification, surveyed the level of national and international research effort at 149 laboratories, visited two major Navy laboratories engaged in auditory research, and drafted a report on its findings. The survey indicated that the study of complex sound is a major topic of auditory research throughout the world and its level of effort is expected to increase over the next five years, especially in the domain of perceptual psychophysics.

PERCEPTUAL SCIENCE

CLUSTER 8

HAPTICS AND SENSORY GUIDED MOTOR CONTROL

TITLE: Object Exploration and Recognition by Humans and Machines

PI: Roberta L. Klatzky
University of California, Santa Barbara
Dept. of Psychology
(805) 961-3948

R&T PROJECT CODE: 4424200 CONTRACT NO: N0001486K0232

CURRENT END DATE: 30 APR 1989

Technical Objective: The objectives are 1) to develop functional relationships between haptic exploration procedures and object properties; 2) to incorporate the functional relationships into a computational model of haptic apprehension and object recognition; 3) to reconcile differences between psychological and robotic models of object recognition by touch and manipulation.

Approach: The approach is an integrated, interdisciplinary program that includes modeling, experimentation and computer simulation by psychologists (Klatzky & Lederman) and computer scientists (Bajcsy).

Progress: An experiment on categorization of objects by multiple attributes has been completed. The data provide convergent evidence that the dimensions of texture and hardness can be extracted in parallel, with gain from redundant category cues. In contrast, combinations of substance and structure attributes do not appear to be integrated.

TITLE: The Cortical Substrate of Haptic Representation

PI: Joaquin M. Fuster
University of California, Los Angeles
UCLA School of Medicine
(213) 825-0247

R&T PROJECT CODE: 4425800 CONTRACT NO: N0001486K0174

CURRENT END DATE: 28 FEB 1989

Technical Objective: The objectives of this research are to: (1) investigate the role of the posterior parietal cortex in the perception and memory of information acquired by touch; (2) elucidate the organization of the neuronal structures that engage in haptic functions; and (3) examine the interactive neuronal processes and mechanisms underlying crossmodal associations involving touch and vision. The research will also explore the potential applications of derived models for the development of improved robotic sensors and effectors.

Approach: This research is guided by recent theories of cortical processing and representation; it is directed at elucidating the functional anatomy and neuronal mechanisms of the posterior parietal cortex, postulated as the site of haptic function. The research will be conducted on macaque monkeys trained to distinguish objects by touch and to remember their size and shape. The roles of various areas of the posterior parietal cortex in haptic and cross-modal information processing will be studied by selective cooling with implanted probes.

Progress: Experiments have been conducted on single unit activity in parietal cortex (total of 456 units in areas 2, 5 and 7) during haptic performance involving matching-to-sample with haptic sample and haptic choice. Results show that changes in cell activity are more complex and of longer duration in area 5 than in area 2 suggesting that area 2 units are involved mainly in haptic discrimination and that area 5 units are involved in cognitive functions such as object recognition and memory.

TITLE: Peripheral Neural Mechanisms of Haptic Touch: Softness & Shape

PI: Robert H. LaMotte
Yale University
Anesthesiology & Neuroanatomy
(203) 785-2802

R&T PROJECT CODE: 4424218 CONTRACT NO: Not yet assigned

CURRENT END DATE: 30 JUN 1990

Technical Objective: The objective is to develop the psychophysical and neurobiological basis for biologically plausible computational models of human hand grasping and object manipulation for potential implementation in teleoperator and robotic devices.

Approach: Psychophysical data from humans and monkeys and physiological data from monkeys will be gathered to determine the capabilities of these systems to discriminate softness and shape, and to determine the neural code underlying these discrimination capabilities.

Progress: This contract is new in FY1988.

TITLE: Neural Feedback and Musculo-Skeletal Mechanics

PI: Emilio Bizzi
Massachusetts Institute of Technology
Department of Brain and Cognitive Sciences
(617) 253-5769

R&T PROJECT CODE: 4424216 CONTRACT NO: N0001488K0372

CURRENT END DATE: 31 MAY 1990

Technical Objective: Objective is to produce biologically plausible computational models of human arm and hand sensorimotor control for potential implementation in teleoperator and robotic devices.

Approach: The approach is a combination of neurophysiological experiments, behavioral investigations, mathematical modeling, and theoretical studies of the computational tasks performed by the brain in the control of motor behavior. Model-based experiments are conducted to quantitatively model movement planning, execution and functional manipulation.

Progress: This contract is new in FY1988.

TITLE: Models for Hand Movement and Teleoperator Control

PI: John M. Hollerbach
Massachusetts Institute of Technology
Artificial Intelligence Laboratory
(617) 253-5798

R&T PROJECT CODE: 4424215 CONTRACT NO: N0001488K0338

CURRENT END DATE: 30 APR 1990

Technical Objective: The objective is to produce biologically plausible computational models of human hand grasping and manipulation for potential implementation in teleoperator and robotic devices.

Approach: The approach is a synthesis of mechanical engineering, biomechanics, and biological motor control and is guided by a competence model of hierarchical movement-planning and control structures. Computer simulation and model-based experiments are conducted to quantitatively investigate human hand and teleoperator trajectory planning, grasping, fine motion control and regrasping at the object, joint, and activator levels.

Progress: This contract is new in FY1988.

TITLE: The Psychophysics of Motor Learning

PI: Christopher G. Atkeson
Massachusetts Institute of Technology
Brain & Cognitive Sciences
(617) 253-0788

R&T PROJECT CODE: 4424217 CONTRACT NO: N0001488K0321

CURRENT END DATE: 30 APR 1990

Technical Objective: The objective is to develop the empirical base for biologically plausible computational models of motor coordination and control for potential application in teleoperator and robotic systems.

Approach: Psychophysical, biomechanical, and kinematic data will be obtained from human subjects to provide an empirical basis for computational models of the parameters explicitly controlled by the nervous system during the learning and performance of skilled motor activity.

Progress: This contract is new in FY1988.

TITLE: Modular Conceptions of Timing and Sequencing in Motor Behavior

PI: Steven W. Keele
University of Oregon
Department of Psychology
(503) 686-4931

R&T PROJECT CODE: 4426802 CONTRACT NO: N0001487K0279

CURRENT END DATE: 31 MAR 1990

Technical Objective: The objective is to carry out behavioral experimentation with normals and brain damaged patients to establish the separability of the modular components of coordinated action and to demonstrate the central neural basis of each.

Approach: Both normals and brain-damaged patients will be tested. Data taken from normals will be used to assess the independence of the timing, force, sequencing, and configuring components of coordinated motor function. Data from brain-damaged patients will be used to establish the anatomical basis of each component function.

Progress: Several studies on the sequencing of motor action have been completed in recent months. The important finding is that sequences of action that do not contain repeated elements can be learned without attention; however sequences with repeating elements cannot. In the latter case, a simple linear association process will not suffice. Rather, a hierarchical representation, which specifies the context in which action elements must be produced, must be invoked. A neural network simulation carried out by the PI shows the same pattern of results.

TITLE: Complex Sensorimotor Behavior: Biological Control Structures and Constraints

PI: J.A. Scott Kelso
Florida Atlantic University
Center for Complex Systems
(407) 338-2230

R&T PROJECT CODE: 4424223 CONTRACT NO: Not yet assigned

CURRENT END DATE: 31 JUL 1991

Technical Objective: To develop the theoretical and empirical base for a unified control theory of motor function applicable across both rhythmic and discrete movement domains.

Approach: To conduct psychophysical and motor performance experiments with human subjects and develop non-linear dynamical analyses the results of these experiments, leading to a formal theoretical formulation of the dynamics of sensory-guided reaching and grasping behavior.

Progress: This contract is new in FY1988.

TITLE: Mechanisms of Eye-Hand Coordination

PI: Apostolos P. Georgopoulos
John3 Hopkins University
Department of Neuroscience
(301) 955-8334

R&T PROJECT CODE: 4424224 CONTRACT NO: Not yet assigned

CURRENT END DATE: 31 JUL 1991

Technical Objective: To elucidate the mechanisms of eye-hand coordination at the psychophysical, neurophysiological, and computational levels.

Approach: To define the behavioral capabilities of human and monkey subjects in eye-hand coordination, to characterize the patterns of activity of single cells in the monkey motor cortex during eye-hand coordination tasks, and to model the involvement of neuronal populations in the motor cortex during the performance of such tasks.

Progress: This contract is new in FY1988.

TITLE: Workshop on Computational Approaches To Neuroscience

PI: Susan Hockfield
Cold Springs Harbor Laboratory
Neurobiology Program
(203) 785-5944

R&T PROJECT CODE: 4424220 CONTRACT NO: N0001488K0378

CURRENT END DATE: 31 DEC 1990

Technical Objective: Objectives are: (1) to conduct interdisciplinary workshops on computational approaches to neuroscience; (2) to identify and test advanced computational models of ocular motor control, vision and sensory guided motor control; and (3) to promote interdisciplinary collaboration and training among scientists working in the life sciences and the physical sciences on research projects in the rapidly growing field of computational neuroscience.

Approach: Senior scientists, graduate students and post doctoral fellows in biology, psychology, computer science, engineering and physics will participate in workshops during the summers over the next three years. The workshops will consist of tutorials and hands-on laboratory sessions during which advanced computational models will be described, implemented and tested in computer simulations. Model results will be compared with actual data sets and the merits of the models will be evaluated.

Progress: This contract is new in FY1988.

TITLE: Attention and Performance XIII: Motor Representation and Control

PI: Sylvan Kornblum
Regents of the University of Michigan
Mental Health Research Institute
(313) 763-1101

R&T PROJECT CODE: 4424209 CONTRACT NO: N0001488J1058

CURRENT END DATE: 28 FEB 1989

Technical Objective: The objective is to disseminate scientific knowledge across the international community of researchers investigating motor schemata, the execution of motor sequences, the control of reaching and manipulation, and the role of position senses in motor control.

Approach: The conference was organized by the principal investigator aided by an international organizing committee. The meeting consisted of five daily sessions covering both theoretical and empirical aspects of sensory-motor function.

Progress: This contract is new in FY1988.

Outside Funding: AFOSR (partial)

PERCEPTUAL SCIENCE

CLUSTER 9

DECISION MAKING

TITLE: EFFECTS OF TASK VARIABLES ON DECISION MAKING STRATEGIES

PI: John W. Payne
Duke University
The Fuqua School of Business
(919) 684-3180

R&T PROJECT CODE: 4425063 CONTRACT NO: N0001480C0114

CURRENT END DATE: 31 JAN 1990

Technical Objective: The purpose of this research is to increase our understanding of how task variables affect the cognitive processes or strategies involved in decision making. The long range objectives are the development of a theory of context effects based on information processing considerations, and the exploration of the implications of that theory for improving human decision making.

Approach: Business management scenarios such as resource allocation and plant location decisions will be utilized to study the decision behavior of MBA students and expert managers. The experiments will focus on (1) variations in task complexity (e.g., number of alternatives, allowed processing time), (2) nature of the alternatives available (e.g., presence or absence of "sure thing" and "ruinous loss" outcomes), (3) formulation of the decision problem, and (4) level of aspiration. Data will include the actual choices made, response times, and the patterns of information acquisition behavior and decision strategies employed, as determined by analysis of verbal protocols obtained from the observers.

Progress: Prior research by Payne has shown that a model of decision effort based on the decomposition of decision strategies could predict decision latencies and self reports of effort with a high degree of success. The predictions were consistent across strategies and levels of aggregation. Current experiments are investigating individual differences in adaptive strategy selection. Preliminary results indicate that subjects for whom certain operators were relatively more effortful show processing patterns indicative of greater use of heuristic, non-compensatory processes, rather than use of computationally intensive strategies like the weighted additive utility rule.

TITLE: A Theory of Diagnostic Inference

PI: Robin M. Hogarth
Center for Decision Research
University of Chicago
(312) 702-7271

R&T PROJECT CODE: 4425080 CONTRACT NO: N0001484C0018

CURRENT END DATE: 14 FEB 1990

Technical Objective: The objectives are to develop a general theory of diagnostic inference by formulating and testing a theory of how causal judgments are made, and by developing a theory of evidence about how people judge ambiguous and uncertain data patterns.

Approach: The approach is a combination of theory development, theory representation by models of delineated form and then by algebraic representation based on results of experiments.

Progress: A model for judgment updating has been developed based on a sequential anchoring-and-adjustment process. The key psychological assumption underlying the process is a contrast effect which is dependent upon sensitivity to evidence. Eight experiments have been completed to test the model's predictions. Results demonstrated that the stronger current opinion, the more it is discounted by negative evidence and the less it is increased by positive evidence; recency effects were observed for mixed evidence, but no order effects for evidence that is either all positive or all negative; primacy effects are exhibited when judgments are elicited at the end as opposed to step-by-step in a sequence.

TITLE: Naval C3 Distributed Tactical Decision Making

PI: Michael Athans & Alexander Levis
Massachusetts Institute of Technology

(617) 253-6173

R&T PROJECT CODE: 411b003 CONTRACT NO: N0001484K0519

CURRENT END DATE: 31 JUL 1989

Technical Objective: The objective of the research is to address theoretical and computational issues that arise in the modeling and analysis of distributed tactical decision making. The research plan has been organized into two highly interrelated research areas: (a) distributed decision processes; and (b) distributed organizational structures.

Approach: Theoretical and experimental investigations are being conducted to develop: (a) models and algorithms for decision strategies of distributed agents with communications restrictions in situation assessment and resource allocation tasks and (b) models for describing and evaluating alternative organizational structures including serial, parallel and multi-echelon structures.

Progress: A computational model, referred to as the performance-workload locus, has been developed for evaluating alternative organizational structures. Models of asynchronous decision process protocols that define coordination points, concurrent operations and random task-completion times have been formulated using stochastic time Petri Nets.

TITLE: Distributed Dynamic Decision Making in Teams

PI: David L. Kleinman
University of Connecticut
Dept of Electrical and Systems Engineering
(203) 486-3066

R&T PROJECT CODE: 442e005 CONTRACT NO: N0001487K0707

CURRENT END DATE: 30 SEP 1989

Technical Objective: Objective is to develop empirical relationships between decision making effectiveness in multiperson teams and a range of organizational, situational and individual variables.

Approach: Approach is to conduct a series of interrelated experimental investigations with decision making teams whose members vary in expertise and risk attitude in threat scenarios that vary in tempo and uncertainty, and who interact in a variety of organizational arrangements.

Progress: A series of experiments on team resource allocation have been recently been completed. The principal performance measures were the timeliness and accuracy in the assignment of resources to individual threats. Results indicated: (a) that team members employed a strategy with short-term planning horizons under high temperature conditions; and (b) that the decision makers tended to coordinate only on the most urgent threat. Data are being analyzed concerning the nature and frequency of conflicts among team members for the use of common resources.

TITLE: Dynamic Decision Models

PI: David Castanon
Alphatech Inc.

(617) 273-3388

R&T PROJECT CODE: 211b002 CONTRACT NO: N0001484C0577

CURRENT END DATE: 25 MAY 1989

Technical Objective: The objective is to develop contributions to an integrated theory of distributed tactical decision making based on theoretical and experimental research in mathematics and psychology.

Approach: The work will consist of two major tasks. The first task will develop mathematical models in team and game theory with emphasis on developing quantitative methodologies for analyzing problems of dynamic decision making under uncertainty. The second task will focus on the development of normative/descriptive models of human decision making. This task will build on theories and models of behavioral decision making.

Progress: The mathematics component of the research program has focused on decision algorithms for finite-state, discrete-time, partially observable Markov decision processes. The basic algorithm is stochastic dynamic programming which involves the temporal decomposition of a dynamic problem into a sequence of static problems. The human factors research has produced a testbed and experimental designs for investigating multi-person information processing and decision making. This component of the program seeks to develop and test normative/descriptive models for information processing and resource allocation functions.

TITLE: Decentralized Resource Management in Tactical Computer Executives

PI: John P. Lehoczky
Carnegie-Mellon University

(412) 268-8725

R&T PROJECT CODE: 211b001 CONTRACT NO: N0001484K0734

CURRENT END DATE: 14 MAR 89

Technical Objective: This research addresses the problem of computer system configuration, i.e., the dynamic assignment and reassignment of data to processing nodes, at the level of the operating system which supports multi-person decision making.

Approach: The technical approach entails the development of: (a) concurrency control theory and mechanisms for decentralized resource management and scheduling; and (b) reconfiguration algorithms to meet changing operational demands. An important feature of the technical approach is to treat the decentralized operating system as a special form of a distributed data base.

Progress: A formal theory of modular concurrency control and failure recovery has been formulated. The theory is a generalization of classical serializability theory and failure atomicity. The rules of the theory provide for the consistency of shared data and allow transactions to be programmed, modified and scheduled independently of the rest of the transactions in the system.

TITLE: DTDM: Information and Schema Theory

PI: David Noble
Engineering Research Associates, Inc.

(703) 734-8800

R&T PROJECT CODE: 411b005 CONTRACT NO: N0001484C0484

CURRENT END DATE: 15 APR 1989

Technical Objective: Formulate and test a theory of information presentation that embodies fundamental elements underlying the effective transfer of complex information among dispersed decision makers. The proposed theory focuses on the refinement of schema as methods to improve the presentation of visually displayed information. Schema, as defined in this theory, are structures which enable situations to be classified and associated with appropriate action rules.

Approach: The theory predicts the relationship between the features emphasized in a situation display and people's assessments of different alternatives for that situation. The theory suggests how situation features should be tailored in order to promote consensus, and what information should be transmitted to effect a common situation understanding. The research tests the theory by varying situation display features under controlled experimental conditions.

Progress: Noble has recently completed pilot studies at the Naval War College to investigate the use of schema-based information displays to support plan generation, situation assessment and plan revision. Preliminary analysis of data and observations indicate that the schema-based displays facilitated recognition of critical events and improved coordination among team members.

TITLE: Distributed Decision Making in a Dynamic Network Environment

PI: A. R. Sastry
Rockwell International Corporation
Science Center
(805) 373-4409

R&T PROJECT CODE: 414k007 CONTRACT NO: N0001487C0703

CURRENT END DATE: 30 SEP 1989

Technical Objective: It is planned to investigate the ability of a network to respond to the mission-related, real-time distributed decision needs considering an integrated environment in which the communication networks and protocols, the distributed operating system, human cognitive processes of the agents, and the DDM methodology interact to accomplish the objectives of a mission.

Approach: The following issues will be considered: modeling an integrated decision making environment, performance assessment methodology for distributed processing systems, methods of handling time-critical traffic in which messages with 'value' functions that decay with time are processed in the network in a dynamic manner so as to maximize the total value of all received messages, and representation of the cognitive processes of human agents (collective and individual) in interacting with the DDM processes and the networks to meet various real time mission needs.

Progress: The Principal Investigator has devised and incorporated into Schemer's design an improved formulation of a set of communication constructs that can be expressed in computational terms and appear adequate to model a very wide range of communication relations among elements of a distributed system. He has also simplified the formulation within Schemer of the individual problem-solving elements thus reducing the number of primitive, formal constructs on which this model is based.

PERCEPTUAL SCIENCE

CLUSTER 10

HUMAN FACTORS TECHNOLOGY

TITLE: Human Factors Committee

PI: Harold P. Van Cott
National Academy of Sciences
National Research Council
(202) 334-3027

R&T PROJECT CODE: 4424167 CONTRACT NO: N0001488RM24005

CURRENT END DATE: 30 NOV 1987

Technical Objective: A committee on basic research on human factors established within the National Research Council/National Academy of Sciences and composed of distinguished experts in the relevant scientific disciplines will, over time, engage in a variety of activities designed to strengthen both theory and fundamental knowledge relating to human factors engineering.

Approach: The committee will -- 1) advise its sponsors regarding the most important basic research needs in the field as a whole and provide guidance on methods for investigating such problems, 2) explore, in depth, the state of knowledge in selected areas judged to be of particular importance as a basis for the development of detailed research agendas in these areas, 3) provide a mechanism for encouraging contact and communication among both basic and applied researchers in the field, both in this country and abroad, 4) attempt to interest outstanding younger scientists and senior persons outside the field of human factors engineering in conducting basic research relevant to major theoretical and methodological issues, and 5) respond to requests from its sponsors.

Progress: During the past year The Committee conducted Working Group meetings on: (1) Expert Systems and Knowledge Elicitation;(2) Distributed Decision Making; and (3) Human Performance Models for Man-Machines Systems. In addition, a symposium on Human Factors in Automated and Robotic Space Systems was conducted and proceedings distributed.

Outside Funding: AFOSR, ARI, NASA, and NSF

TITLE: Computational Models for Maintainability Design

PI: Douglas M. Towne
University of Southern California
Behavioral Technology Laboratories
(213) 540-3654

R&T PROJECT CODE: 4429004 CONTRACT NO: N0001486K0793

CURRENT END DATE: 14 AUG 1988

Technical Objective: The proposed research is directed towards: (a) the formulation of predictive models of maintenance technician performance as a function of equipment design features; and (b) the extension of these models as computational tools for the maintainability design of systems.

Approach: The Principal Investigator has developed an innovative approach for integrating models of trouble-shooting and repair performance with computer-aided design and engineering (CAD-CAE) methods. Current CAD-CAE methods, although computational powerful, are limited to analyzing physical and geometric design parameters; CAD technology has not produced the models and programs necessary to predict maintenance actions or to evaluate the maintainability consequences of possible alternative designs. This research addresses those important technology needs.

Progress: The principal investigator has developed quantitative methods for predicting the impact of alternative equipment designs upon fault isolation and repair workload. The approach rests upon a general model of maintenance technician performance which, when applied to a range of malfunction conditions, yields projected diagnostic sequences and associated performance times for each malfunction analyzed. Working with the CAD division at NOSC, significant progress has been made to integrate the performance models into a CAE environment.

Outside Funding: ONT

TITLE: Workshop on the Application of Decision Research To Decision Support Systems

PI: Virginia E. Holt
American Psychological Association

(202) 955-7600

R&T PROJECT CODE: 4424804 CONTRACT NO: N0001487G0146

CURRENT END DATE: 14 MAR 1988

Technical Objective: The objective of this work unit is to investigate the extent to which research on decision making has been and could be used to improve the effectiveness of decision aiding systems. In addition, a research agenda will be formulated that will address both basic research issues as well as applied research topics that would advance the application of research findings to future Naval systems.

Approach: A workshop will be conducted: (1) to review recent findings in behavioral decision research, mathematical/statistical research and organizational research; (2) to evaluate their potential for application to decision aiding systems; and (3) to document illustrative instances of the implementation of classes of decision models and characterize their effectiveness. Approximately 15 leading researchers in the field of decision science will participate along with about 25 developers and users of decision aiding technology, particularly in the area of military command and control.

Progress: The workshop was conducted at the National Academy of Sciences during May 1987. Proceedings have been prepared as a technical report and distributed to the scientific community.

Outside Funding: ONT (partial)

TITLE: Theory-Based Decision Models for Tactical Decision Aiding

PI: Marvin S. Cohen
Decision Science Consortium Incorporated

(703) 790-0510

R&T PROJECT CODE: 4429009 CONTRACT NO: N0001485C0642

CURRENT END DATE: 14 SEP 1988

Technical Objective: This research is concerned with understanding factors affecting human decision performance and modeling information processing functions. The results of this research will provide a basis in decision theory for the development of personalized and prescriptive tactical decision aids for advanced Navy command and control systems.

Approach: Conduct experimental research on tactical decision processes and develop theory-based models for submarine tactical decision aiding with a focus on attack planning. Extend the concepts of personalized and prescriptive aiding to decision processes regarding target ranging, classification, own ship maneuvering, counterdetection and target engagement. Investigate inferential processes used in judgments of uncertain estimates and the effects of ambiguity and framing on tactical decisions. Implement an experimental attack planning aid in the combat simulation facility at NUSC, Newport.

Progress: Most recent work has been concerned with experiments on decisions involving the tradeoff between delaying an attack in order to increase the probability of a hit, and firing earlier to avoid being counterdetected. Experiments focused on the effects of the following variables: ambiguity in probability estimates, framing of outcomes, target importance and range estimation (inference) based on multiple uncertain sources. Results will be used as a basis for adaptive and prescriptive decision aiding.

Outside Funding: ONT

TITLE: Information Processing Models for Adaptive Computer Interfaces

PI: Wayne W. Zachary
CHI Systems Incorporated
President and Principal Scientist
(215) 277-2355

R&T PROJECT CODE: 4429007 CONTRACT NO: N0001487C0814

CURRENT END DATE: 29 SEP 1989

Technical Objective: To formulate computational models underlying information processing of the Tactical Coordinator in airborne ASW mission management. Based on these models, develop an adaptive computer interface for mission management which adjusts its computations to the attention flow of the operator and the evolution of mission events.

Approach: Theoretical formalisms for planning and problem solving such as Newell's Model Human Processor and Hayes-Roth's Blackboard Model are extended and merged to develop computational models of information processing and decision making. These models are used in conjunction with A.I. techniques for plan recognition to provide a basis for an adaptive interface for mission management. Experiments are conducted to test the models and adaptive interface.

Progress: Two lines of work have been pursued, viz.,1) the development of an updated airborne ASW tested; and 2) an elaboration of the theoretical and modeling framework. The SUN 3/60 workstation was selected and procured for the experimental environment. Computer programming is well underway with the cooperation of the technical staff at NADC. The testbed will be capable of simulating tactical air ASW missions, and emulating critical elements of the airborne tactical coordinator's computer interface and workstation. Significant progress has been made in expanding the formalisms of the GOMS model and the blackboard architecture using tasks required by the TACCO in ASW mission management.

Outside Funding: ONT

TITLE: Modeling Human-Computer Interaction

PI: Allen Newell
Carnegie-Mellon University
Department of Psychology
(412) 578-2806

R&T PROJECT CODE: 4429005 CONTRACT NO: N0001487K0432

CURRENT END DATE: 31 MAY 1989

Technical Objective: To extend a predictive model of human performance (Model Human Processor) for interaction with computing systems by decomposing composite operators (perceptual, motor, and cognitive), estimating their boundary conditions, introducing weighting factors to account for individual differences, and focussing on the stimulus-response compatibility of various user tasks.

Approach: Response-time data that are available in the literature are analyzed for their operators (perceptual, motor, cognitive, etc.), and the stability of their measures, in order to develop predictive models of human response times for various human-computer interaction tasks. The SOAR general cognition theory is utilized to provide a formal language that allows simulations to be run on those human performance data to evaluate, quantitatively, learning mechanisms, perceptual processes, and problem-solving procedures.

Progress: Studies have been conducted on the estimation of parameters for task compatibility, choice of stable measures for those tasks, and the selection of measures that take into consideration the range of individual differences that appear in the archival literature.

Outside Funding: ONT (partial)

TITLE: On Line Aiding for Human-Computer Interfaces

PI: Jay Elkerton
The Regents of the University of Michigan
Dept. of Industrial and Operations Engineering
(313) 763-0464

R&T PROJECT CODE: 4429008 CONTRACT NO: N0001487K0740

CURRENT END DATE: 14 AUG 1990

Technical Objective: To develop human performance models for online aiding and online instruction for procedural knowledge with computer-based systems. To validate models for the tasks of text-editing, file-searching, and computer-aided design. To develop usability indices for the identification and measurement of the critical performance components of written and graphical dialogues.

Approach: Extend the Model Human Processor of Newell et al. to include the quantitative analysis of the components that are elicited during online graphic aiding with computer-based systems. Conduct experimental studies to validate the model and to derive usability indices of task design.

Progress: Prior research on online aiding and online instruction were reviewed critically and the resulting analysis was published as a technical report.

Outside Funding: ONT (partial)

TITLE: Goal and plan knowledge in software comprehension

PI: Scott P. Robertson
Rutgers University
Department of Psychology
(201) 932-3670

R&T PROJECT CODE: 4424203 CONTRACT NO: N0001486K0876

CURRENT END DATE: 30 SEP 1989

Technical Objective: To develop a cognitive model of task comprehension, using the task of revising software code, that emphasizes the role of language constructs and syntax, the organization of planning knowledge, and the understanding of goal knowledge. To predict the effects of plan structures and the role of sources of the programmer's knowledge on the understanding of software code.

Approach: Experiments are conducted to determine how the representation of software code as episodic and semantic traces for the programming statements and abstract concepts about the program are encoded and influence the understanding of the program. Further experimental studies are made to explore the sources and utilization of knowledge available to the programmer for understanding the program.

Progress: The theory that programmers utilize a plan-based representation when comprehending software code was supported in a series of experimental studies during which programmers segmented and sorted programs written in either FORTRAN or PASCAL languages. The majority of the sub-goals that make up the plan representation were abstract, with few that were task- specific.

TITLE: Strategies for Understanding and Maintenance of Large-Scale Software Systems

PI: Thomas G. Moher
University of Illinois at Chicago
Dept. of Elec. Engineering and Computer Sci.
(312) 996-4562

R&T PROJECT CODE: 4429006 CONTRACT NO: N0001487K0413

CURRENT END DATE: 14 NOV 1988

Technical Objective: To ascertain problem-solving strategies associated with the search of large information systems in order to test theories of problem identification based on discrete and distributed search strategies, and to develop metrics that characterize search strategies and quantify their accuracy and efficiency.

Approach: Conduct experiments with experienced programmers engaged in the task of modifying software code of at least 20K lines in size. Electronic, audio, and video recordings are collected of user performance during this task and the data are analyzed to define and measure the search and problem-solving strategies that are adopted by the users.

Progress: Experimental results have been interpreted within a model of task comprehension driven by search in a planning space where the desired modification-plan is directed toward two reference regions in a program space, i.e., the current and desired state of the program. A third element in the model is knowledge in a task-domain space which constrains the search of the program space. Rather than a singular strategy for large systems, the evidence suggests opportunistic processing and localized strategies that focus on sub-plans and distinctive features of the task.

TITLE: Supervisory Control for ARGO/JASON

PI: Dana R. Yoerger
Woods Hole Oceanographic Institution

(617) 548-1400, Ext. 2608

R&T PROJECT CODE: 222c001 CONTRACT NO: N0001486C0038

CURRENT END DATE: 30 NOV 1989

Technical Objective: The objective of the work is to develop and test supervisory control models for the ARGO/JASON underwater search and inspection system. Current efforts are focussed on: (a) control models, sensing mechanisms and kinematics for the remote manipulators; (b) methodology for coordinated control of the JASON vehicle and dual manipulators; and (c) design of a master controller and investigations of force reflection and programmable impedance.

Approach: The technical approach includes mathematical modeling, computer simulations, man-in-the-loop experiments, and full scale equipment trials both in a test tank and at sea. The ARGO/JASON project is jointly funded by the Undersea Surveillance and Human Factors Technology Program Elements; the human factors work focusses on models for the control of the vehicle and manipulations, design of the master controller and graphic displays.

Progress: A highlight of FY88 was a trial that illustrated several key elements of the JASON supervisory control system during an interactive, computer-controlled hull survey of the USS Philadelphia (688 class SSN) dockside in New London using the JASON Jr. vehicle. The test successfully demonstrated a supervisory control system that included precision acoustic navigation, closed-loop control, a geometric model of the submarine, and an interactive graphic display.

Outside Funding: ONT

TITLE: Integrated Computational Models of Perceptual Performance

PI: William R. Uttal
Arizona State University
Department of Psychology
(602) 965-3326

R&T PROJECT CODE: 4429011 CONTRACT NO: Not yet assigned

CURRENT END DATE: 31 JUL 1990

Technical Objective: To develop and test a software system for the integration of existing algorithms for computing the detection, localization, and classification of objects in the 3-D world. To evaluate the utility of the resulting system as a test bed for the evaluation of computational algorithms yet to be developed.

Approach: To collect and integrate a collection of individual computational algorithms into a coherent software system capable of simulating the performance of a 'swimmer' that is required to detect and recognize regular geometrical objects, locate them in 3-D space, and then navigate toward them.

Progress: This contract is new in FY1988.

Outside Funding: ONT

BIOLOGICAL INTELLIGENCE

CLUSTER 11

COMPUTATION IN LARGE NEURAL NETWORKS

TITLE: Changes in Neuronal Network Properties Induced by Learning and Synaptic Plasticity: A Nonlinear Systems Approach

PI: Theodore W. Berger
University of Pittsburgh
Dept of Behavioral Neuroscience
(412) 624-4562

R&T PROJECT CODE: 4426817 CONTRACT NO: N0001487K0472

CURRENT END DATE: 31 MAY 1990

Technical Objective: Investigate potential changes in system properties of the hippocampus induced by discrimination reversal conditioning of the nictitating membrane (NM) response. Classical conditioning of the rabbit NM response will be used in these experiments because it is one of the most widely used behavioral paradigms for the studying of the neuronal substrates of associative learning in mammals.

The second objective is to produce a computational structure which simulates the hippocampal system functions of learning and memory. The computer model will be organized into hierarchical structure. The basic unit will be the state transition information developed experimentally. Local domains will be defined which represent highly integrated sets of neurons, having connectivity rules, but conceived of as functioning as a unit. The behavior of a domain will be constrained by the explicitly derived state-space model and by known anatomical and physiological properties of the hippocampus.

Approach: The approach of this proposal is an in-depth study of the functional network properties of the hippocampal formation, a brain structure long known to be critical for learning and memory functions. The first phase utilizes nonlinear systems analytic techniques to characterize the transformational properties of networks of neurons comprising the hippocampus, and in defining the contributions to network properties of individual subpopulations of hippocampal neurons. The second phase, involves the formulation of a state-space model of hippocampal system function based on results from the nonlinear systems characteristics of the hippocampal system are altered by associative learning. Such learning-independent changes in system function will be incorporated into the state-space model.

Progress: Equipment has been purchased , graduate students hired, and experiments begun.

TITLE: Computational Theory and the Olfactory System

PI: James M. Bower
California Institute of Technology
Biology
(818) 356-6817

R&T PROJECT CODE: 4426136 CONTRACT NO: Not yet assigned

CURRENT END DATE: 30 JUN 1991

Technical Objective: The overall objective of the proposal is to attempt to forge a link between the components of abstract neural network processing and the detailed anatomy and physiology of an actual neural system. This proposal links the more theoretical neural network models studied by Hopfield and his group to the actual structural components of the olfactory system studied by Bower and his lab. This linkage will be performed using the neural network simulation facility that has been constructing at Caltech. The simulation engine for this facility is a hypercube class parallel superconducter, which provides adequate computational power to efficiently model both abstract networks and realistically specified neural systems. The olfactory system represents an excellent choice to undertake the synthesis of reality and theory and will advance the understanding of both applied and real neural networks.

Approach: This project will develop physiological techniques for recording neuronal activity in behaving animals (albino rats). Initially, this approach will involve recording simultaneously from numerous neurons in the mitral cell layer of the olfactory bulb while the animal is performing olfactory discrimination tasks. In these experiments, the primary objective will be to determine the nature of stimulus encoding the olfactory system and the role of this encoding in learning and memory. This information will be of great significance to both computational and simulation efforts.

Progress: This contract is new in FY1988.

TITLE: Dynamic Biophysical Theory for the Role of Hippocampal Neural Networks in the Declarative Memory System

PI: Thomas H. Brown
Yale University
Department of Psychology
(818) 357-9711

R&T PROJECT CODE: 4426200 CONTRACT NO: N0001488K0313

CURRENT END DATE: 30 JUN 1991

Technical Objective: The objective is an understanding of how the circuitry of the hippocampus carries out its adaptive functions. The network level model will have three features.

1. It will capture the time-dependent aspects of neural computation, i.e., the neurodynamics.

2. It will show how the neurodynamics emerge from the cellular neurophysiology and biophysics.

3. The model will be tightly linked to experimental knowledge of the cellular neurophysiology and biophysics.

Approach: Using brain slice techniques, whole neurones will be examined to form realistic representations of the principle neuronal types (e.g. CA1 and CA3 pyramidal neurones, granule and basket cells). Voltage signalling throughout the dendritic authorization will be explored. In addition, I/O (synaptic input to spike output) will be quantified to understand the adaptive network neurodynamics.

Progress: This contract is new in FY1988.

TITLE: Neuroanatomical Studies of Nested Parallel Information Processing Pathways

PI: Peter C. Brunjes
Rector & Visitors of the University of Virginia
Psychology
(804) 924-0687

R&T PROJECT CODE: 4426015 CONTRACT NO: N0001486K0342

CURRENT END DATE: 30 MAY 1988

Technical Objective: The studies are designed to rigorously characterize the topography of projections into the main olfactory bulb, and then trace the organization of the three-way parallel processing system which receives the information and transmits it to higher brain regions. The final objective is a fine-scale analysis of the anatomical underpinnings of a complex information processing circuit.

Approach: A developmental approach has been taken because it allows for the utilization of spatio-temporal gradients of maturation to delineate the anatomical foundations upon which the parallel processing systems are built. By examining the development of the system, the establishment of the circuitry and the basic foundations of the wiring diagram can be observed without having to deal with confounds found in highly elaborated adult states.

Progress: The PI has completed an examination of metabolic development in the olfactory bulb, an examination of the effects of odor deprivation on olfactory bulb development, a quantitative study of early development changes in cellular number and packing density in the olfactory bulb, and an examination of early cellular proliferation in the olfactory bulb.

TITLE: Theoretical and Experimental Research into Biological Mechanisms Underlying Learning and Memory

PI: Leon N. Cooper
Brown University
Center for Neural Science
(401) 863-2585

R&T PROJECT CODE: 4426830 CONTRACT NO: N0001486K0041

CURRENT END DATE: 31 DEC 1987

Technical Objective: The detailed objectives include the following: to clarify the dependence of learning on synaptic modification, to elucidate the principles that govern synapse formation or modification - both local factors and global information such as that which may be delivered and/or mediated by acetylcholine and catecholamines such as norepinephrine, to use principles of organization that can account for observations on a cellular leel to construct network models that can compute, learn, associate and reproduce such higher level cognitive acts as abstraction, language acquisition, and speech recognition.

Approach: The approaches employed to achieve the objectives include both theory and experiment. Theoretical and experimental consequences of the hypothesis that synapse modification is dependent on local information (in visual cortex, dominated by the inputs from the eyes with specific visual information) in accordance with theoretical ideas the authors have developed, as well as by global instructions affecting large numbers of synapses and coming perhaps from modulatory transmitters such as norepinephrine have been tested. In addition, various principles that appear to be operating on the cellular level will be used to construct models of higher level functions, including various network models for memory storage, computation and language acquisition.

Progress: This contract is new in FY1988.

TITLE: Selective Recognition Automata

PI: Gerald M. Edelman
Neurosciences Research Foundation, Inc.

(212) 570-8975

R&T PROJECT CODE: 4426129 CONTRACT NO: Not yet assigned

CURRENT END DATE: 30 APR 1991

Technical Objective: The major goal of this project is to carry out critical tests of the neuronal group selection theory that will bring selective automata closer to practical application. Some of the specific technical objectives will be to account for the regulation of plastic changes in topographic cortical maps, to show how reentrant connections can assure concordance in maps arising from different sensory modalities, to demonstrate associative learning and conditioning in selective recognition systems, to study mechanisms for figure-group discrimination and perceptual constance in selective systems, to generalize the concept of topographic maps to encompass "cognitive maps" in world-centered coordinate frames, and to find ways to represent temporal sequences of events in selective network systems.

Approach: An approach called "synthetic neural modelling" will be applied to the objectives. This approach depends on starting with a coherent theory of brain function and testing that theory by constructing model automata that follow principles of biological evolution and development. The neuronal networks within the automata are simulated consistently with current anatomical and physiological data. Tests are devised in which there is no prior labelling or classifying of objects in the world, and the results are checked for consistency, both internally and with experimental data whenever possible. A special-purpose network simulation device will be designed and constructed to facilitate the research and to begin the investigation of practical devices based on selection principles.

Progress: This contract is new in FY1988.

TITLE: Intracerebral Neuronal Grafts:Enhanced Cognitive Performance

PI: Fred H. Gage
The Regents of the University of California
Neurosciences
(619) 452-2416

R&T PROJECT CODE: 4426016 CONTRACT NO: N0001486K0347

CURRENT END DATE: 31 MAY 1989

Technical Objective: To determine whether the rate of learning of an individual can be accelerated by providing neural circuitry. To determine whether memory storage and/or retrieval can be expanded by the addition of appropriate cells and circuits. To determine whether grafted tissue can be conditioned to act as a parallel processor and thereby substitute for lost intrinsic connections.

Approach: Intracerebral grafting to the brains of experimental animals has reached a stage of technological development where this procedure can now be used to address a variety of questions in neurobiology. This state-of-the-art intracerebral grafting technology is used to determine whether the performance of a normal intact animal can be enhanced by the addition of neural tissue to specific regions of the host brain.

Progress: Given the short time during which the PI has been receiving money on this contract, remarkable progress is being made. Equipment has been purchased and preliminary experiments have begun.

TITLE: Neural Mechanisms of Representation and Categorization

PI: Richard Granger
University of California, Irvine
Center for the Neurobiology of Learning and M
(714) 856-6360

R&T PROJECT CODE: 4426829 CONTRACT NO: N0001487K0838

CURRENT END DATE: 14 SEP 1988

Technical Objective: Primary interest will be on the categorization of cues, a process that occurs in the present simulation. This involves the generation of two classes of output signals (activity in a particular subset of "neurons") by the simulation for a given input, one that represents that signal and a second that denotes its group where a group is defined as a set of inputs with overlapping components. Experiments will then be run to determine the effects of varying specific network parameters on the "utility" of the categories generated by the model, with utility being determined by a mathematical model derived from information theory (see below). As features and parameter values that increase category ability are discovered, we will initiate three lines of experimental work: First, do changes in the simulation that increase category utility increase the neurobiological "validity" of the model; this will require anatomical and physiological studies of features crucial to category utility. Second, simulation studies will be run to measure the effects of optimizing category utilities on other vital aspects of olfactory behavior, including signal detection,

Approach: The approach includes a combination of neuroscience and behavioral techniques that will provide data for computer simulation and hardware modeling of the actual brain circuits involved in accomplishing cognitive tasks.

Progress: This contract is new in FY1988.

TITLE: Synaptic Structural Effects of Long Term Potentiation in the Hippocampal Formation

PI: William T. Greenough
University of Illinois
Psychology
(217) 333-4472

R&T PROJECT CODE: 4426635 CONTRACT NO: N0001485K0587

CURRENT END DATE: 31 JUL 1988

Technical Objective: Anatomic and physiological experiments will focus on an information storage model in the hippocampus (long-term potentiation). The objective is to categorize the type of shape changes that are seen in the neuronal connections (synapses), how long they persist, and some possible mechanisms underlying them.

Approach: Approach involves production of long-term potentiation in in vitro hippocampal slice preparations. Synaptic contact length; synaptic apposition cone length; presynaptic terminal size, shape, vesicle density; and polyribosomal aggregate location will be measured in these preparations using freeze-fracture anatomic techniques and reconstructing synapses from serial thin sections.

Progress: In the hippocampal slice (CA 1), using liquid nitrogen freezing and freeze substitution, the PI has found increases in the density of the dendritic shaft and sessile spine synapses after LTP. The results suggest a rapid synaptogenesis process associated with LTP potentially involving a shaft to sessile spine to mature spine sequence.

TITLE: Learning in massively parallel networks

PI: Geoffrey Hinton
Carnegie Mellon University
Computer Sciences
(412) 578-2573

R&T PROJECT CODE: 442b467 CONTRACT NO: N0001486K0167

CURRENT END DATE: 14 JAN 1988

Technical Objective: The objective is to develop a deeper understanding of learning in biological hardware. The effort will bring the study of cognitive phenomena closer to biological reality by (a) exploring ways in which the assumptions that make the PI's computational models work (produce outcomes qualitatively similar to those of humans) might be brought in line with biological fact, and (b) by applying the PIs' computational experience in the ongoing exploration of the properties of neural synapses. The broad goal is to contribute to the development of a real interdisciplinary program that combines biological, psychological, and computational research.

Approach: The approach will be to design a series of computer simulations which embody successively more complex versions of the PIs' current models, and to use these simulations to evaluate the models' computational and psychological sufficiency.

Progress: Work on this project has led to (1) development of a powerful new neural network learning algorithm, called the generalized delta rule, (2) systematic tests of the ability of this algorithm to "scale up" to increasingly larger neural networks, and (3) application of the algorithm to Hopfield nets, resulting in a demonstration that it is an effective learning rule in this context.

TITLE: Studies in Neural Networks

PI: John J. Hopfield
California Institute of Technology
Chemistry
(818) 356-6034

R&T PROJECT CODE: 4426803 CONTRACT NO: N0001487K0377

CURRENT END DATE: 31 MAY 1990

Technical Objective: To put the olfactory problem in biology into a computational perspective; to construct model neural networks which can solve some of the computational problems of olfaction; to examine the connections between the model networks and the real olfactory networks; to understand the importance of the time-dependent aspects of olfactory processing. To study the effectiveness of neural networks at Quadratic Match problems; to conceptualize the ways in which this problem can be mapped onto an optical system; to examine the range of interesting problems which a Quadratic Match computer could do. To work on the theory and practicalities of the processing of speech-like signals by artificial neural networks, and look for connections between such networks and neurobiology.

Approach: The dominant approach is through studying the mathematics of the computations involved, and simulations of appropriate neural networks on conventional computers. In olfaction, important experimental input to the research is important, both from past work and on-going work at Caltech. In the case of speech, experimental data will be obtained by purchasing some electronics for the purpose of data acquisition from real verbal signals.

Progress: This contract is new in FY1988.

(Note: Cofunded with Electronics, ONR Code 1114.)

TITLE: Adaptive Control of Limb Motion by Brains and Robots

PI: James C. Houk
Northwestern University
Department of Physiology
(312) 908-8219

R&T PROJECT CODE: 4426126 CONTRACT NO: N0001488K0339

CURRENT END DATE: 30 MAY 1990

Technical Objective: The proposal is designed to advance knowledge about how the cerebellum might mediate adaptive feedforward control, and to apply this information to robotics.

Approach: The investigators will conduct computer simulations of motor systems, in the form of simulated neural networks, that are based on the anatomy and physiology of the cerebellum. More specifically, the investigators are interested in the functional and computational significance of the findings that will result from the mapping of mossy-fibre inputs to cerebellar cortex. Consequently, the investigators will develop and simulate networks of neuron-like units whose architectures and roles in motor control are based on anatomical and physiological knowledge.

Progress: This contract is new in FY1988.

TITLE: 1988 Winter Conference on Neurobiology of Learning and Memory at Park City

PI: Raymond P. Kesner
University of Utah
Psychology
(801) 581-7430

R&T PROJECT CODE: 4426821 CONTRACT NO: N0001488J1045

CURRENT END DATE: 30 JUN 1988

Technical Objective: Understanding the mechanisms underlying learning and memory requires comprehension of the structure and function of the brain structures involved. This information may provide suggestions for improving learning processes, and possibly for alternate hardware architectures.

Approach: The conference is being organized by the principal investigator with the aid of an organizing committee. Meeting will take place at Park City Utah, and will consist of six tutorial/seminar/discussion sessions.

Progress: Not applicable.

TITLE: Dynamic Biophysical Theory for the Role of Hippocampal Neural Networks in the Declarative Memory System

PI: Christof Koch
California Institute of Technology
Div. of Biology & Engineering and Appl.Sci.
(818) 356-6855

R&T PROJECT CODE: 4426201 CONTRACT NO: N0001488K0297

CURRENT END DATE: 30 JUN 1991

Technical Objective: Koch will develop appropriate algorithms for carrying out hippocampal simulations. One focus will be the detailed biophysical events possibly underlying induction of LTP in dendritic spines and single pyramidal cells. In parallel, the second focus will be a network model of the entire hippocampal structure. The two models will provide an organizational substrate to suggest and generate new biological experiments.

Approach: In collaboration with a second ONR contractor, the PI proposes to begin construction of a viable and testable network-level theory of the nature of the information processing that occurs in mammalian central nervous systems. The theory will combine the best neural modelling techniques with state-of-the-art cellular neurobiological experimentation. This contract represents the higher-level or top-down (computational) approach that will serve to guide the bottom-up (neuroscience) strategy.

Progress: This contract is new in FY1988.

TITLE: Methods in Computational Science

PI: Christof Koch
California Institute of Technology
Division of Biology
(818) 356-6855

R&T PROJECT CODE: 4426130 CONTRACT NO: N0001488J1107

CURRENT END DATE: 30 SEP 1988

Technical Objective: The course will survey basic computer modelling techniques used to study single cells and neural networks. Emphasis will be placed on exploring their roles in information processing. The principal objective of the course is to enable participants to simulate the functional properties of systems of interest to them and to understand in general advantages and pitfalls of this computational approach to understanding the nervous system.

Approach: Between more formal lectures on these subjects, students will be expected to implement and test their own simulations in the computer laboratory. State-of-the-art single-user color work stations (SUN3-260) will be provided for this purpose. These computers will run general-purpose neural network simulating software that has been developed at Caltech and other network research centers, reducing the need for fundamental code writing. However, because of the heavy computer orientation of the lab section of the course, a strong computer background will be required.

Progress: Not applicable.

TITLE: Organization of Large Scale Cortical Network

PI: Gary Lynch
University of California, Irvine
Center for Neurobiology of Learning & Memory
(714) 856-4274

R&T PROJECT CODE: 4426019 CONTRACT NO: N0001486K0333

CURRENT END DATE: 30 JUN 1989

Technical Objective: Work will provide quantitative descriptions of the organization of the lateral olfactory tract inputs to superficial layers of piriform cortex, the excitation-inhibition cycles that occur when these inputs are activated, and rules governing their plasticity. Analyses of how the superficial layers are connected to and interact with the deep layers of the cortex will also be conducted. In parallel with these experiments, chronic recording will be used to study the physiological activities of piriform cells as animals sample novel and familiar odors in a successive, olfactory-discrimination paradigm. Additional experiments will examine the hypothesis that previously observed effects of experience on the induction of synaptic plasticity in the piriform cortex are due to hippocampal activity mediated through cholinergic cell populations in the basal forebrain.

Approach: The approach includes a combination of neuroscience and behavioral techniques that will provide data for computer simulation and hardware modeling of the actual brain circuits involved in accomplishing cognitive tasks.

Progress: Simulation work continues to support the idea that models of networks can be used to explore the consequences of specific physiological properties (many germane to LTP) on behavior. The simulation has begun to fulfill a second function: raising experimentally testable questions about LTP that might otherwise go unstudied (e.g. ordering effects, interactions between different LTP episodes, etc.).

TITLE: Silicon Neural Systems

PI: Carver A. Mead
California Institute of Technology
Computer Science
(818) 356-6841

R&T PROJECT CODE: 414e341 CONTRACT NO: N0001487K0353

CURRENT END DATE: 28 FEB 1989

Technical Objective: The objective is to develop a deeper understanding of the collective computational capability of neural systems and to use silicon fabrication technology to implement these neural systems on silicon.

Approach: The approach is to investigate the way the sensory systems process information, including the visual system, the auditory system, and sensory-motor feedback. Adaptation in neural systems and inhibitory feedback will be investigated. Silicon chips for analog computation that is similar to the retina and the cochlear will be designed based on the understanding of these sensory systems. Analog silicon systems the learn will be investigated using electrically-erasable floating-gate memory technology.

Progress: This contract is new in FY1988.

(Note: Cofunded with Electronics, ONR Code 1114.)

TITLE: Neurons, Nodes and Networks

PI: Lynn Nadel
University of Arizona
College of Arts and Sciences
(602) 621-5497

R&T PROJECT CODE: 4426127 CONTRACT NO: N0001488J1076

CURRENT END DATE: 01 JUL 1988

Technical Objective: The meeting will acquaint the neurobiologists with concepts regarding large-scale organization and functional integration of the nervous system. It will acquaint the cognitive/computational scientist with some of the possibilities inherent in biological information processing.

Approach: Three days of meetings (a.m., p.m., and evenings) will bring together more than twenty speakers and discussants approaching the area of neural networks from both cognitive/computational and neurobiological perspectives.

Progress: Not applicable.

TITLE: Procedural and Declarative Learning: Distinctions and Interactions

PI: Mary J. Nissen
Regents of the University of Minnesota
Psychology
(612) 635-9837

R&T PROJECT CODE: 4426555 CONTRACT NO: N0001486K0277

CURRENT END DATE: 14 JUN 1989

Technical Objective: The aim of the proposed work is to address a number of critical questions pertaining to the relationships between procedural and declarative knowledge acquisition. This research will guide theoretical work on the dissociation of mental and brain structures and processes supporting procedural and declarative learning. The practical impact of the research relates to ways to optimize the training of skills and ways to assess expertise.

Approach: Methodologies developed in the cognitive sciences and the cognitive neurosciences will be used to uncover the structure and operation of processes underlying to acquisition of procedural and declarative knowledge.

Progress: The role of attention in procedural versus declarative learning has been elucidated, and the interaction between the attention factor and the Alzheimers syndrome has been determined.

TITLE: Biological Relevance of Neuron-like network learning models.

PI: David Rumelhart
Stanford Junior University
Institute for Cognitive Science
(619) 534-2993

R&T PROJECT CODE: 4426804 CONTRACT NO: N0001487K0671

CURRENT END DATE: 31 AUG 1990

Technical Objective: The objective is to develop and empirically test a biologically plausible model of the processes by which the synaptic efficiencies involved in learning are modified through experience. The project involves a unique combination of theoretical and empirical work at the level of neurobiology in an effort to better understand the fundamental mechanisms of neural plasticity.

Approach: A two-pronged approach will be taken. The first prong, which may be characterized as 'top down', involves beginning with the learning procedures the PI has found useful in his computational work and framing biologically plausible hypotheses about the neural machinery that could implement these procedures. The second prong, which is 'bottom-up' in flavor, involves beginning with the known facts of particular brain structures involved in learning and examining whether the PI's models are consistent with what is discovered about the anatomy and physiology of these structures.

Progress: This contract is new in FY1988.

TITLE: Experimental and Computational Models of Neural Network Learning

PI: Terrence J. Sejnowski
Johns Hopkins University
Dept of Biophysics
(301) 338-8687

R&T PROJECT CODE: 4426822 CONTRACT NO: N0001488K0198

CURRENT END DATE: 30 MAY 1992

Technical Objective: The P.I. has developed a combined in vitro hippocampus-entorhinal cortex slice preparation which includes both the intact hippocampal trisynaptic circuit, and input/output sites in entorhinal cortex. Studies in this preparation will focus on network interactions between cellular groups and how these are altered by the induction of long-term changes in cellular excitability. These studies will be combined with computer simulation of a neuronal network with connections faithful to hippocampal anatomy and processing units emulating important characteristics of hippocampal neurons.

Approach: The approach of the problem of deciphering information storage and retrieval in the brain is to use the tools and techniques for simulating large parallel networks of processing units that have been developed for connectionist network models and apply them to the brain areas that are known to have roles in learning and memory. Not enough is known to completely constrain these models, so additional constraints will be sought by performing experiments on brain tissue that critically test the assumptions and predictions of the models. The goals is to co-evolve the experimental design and the models toward a better understanding of the principles that govern network learning in the brain.

Progress: This contract is new in FY1988.

TITLE: The Organization of Memory

PI: Larry R. Squire
The Regents of the University of California
Dept of Neuroscience
(619) 453-7500

R&T PROJECT CODE: 4426023 CONTRACT NO: N0001486K0738

CURRENT END DATE: 31 AUG 1989

Technical Objective: Work is directed towards understanding how memory is organized in the brain. Human studies will determine what kinds of procedural knowledge are acquired when learning occurs, how long it lasts, and how (if at all) such knowledge influences or otherwise interacts with conscious remembering. Primate experiments are directed towards defining a structure and physiological mechanisms which does not itself store memory but which serves to address, organize, or otherwise support memory storage sites for a limited period after learning.

Approach: Human work will initially proceed by taking autonomic measures (skin conductance responses) during learning and retention sessions in amnesic patients and control subjects. It will be determined whether these or other measures taken at the same time are intact, whether they convey information about otherwise forgotten material, and whether they influence conscious remembering. The monkeys will be given small, neurosurgical lesions to damage or disconnect structures within the medial temporal region of the brain. Behavioral tasks will precisely define the nature of the memory deficit.

Progress: Bilateral medial-temporal lesions produced retrograde amnesia cover- ing at least eight months with no evidence of a temporal gradient (in cynomolgus monkeys). Squire et al. Psychobiology, 15, 37-47, 1987. PI obtained clinicopathalogical information from a patient that developed amnesia at age 52 after an ischemic episode. Normal IQ except impaired performance on memory tasks. Data show discrete bilateral lesion of hippocampal CA1 field thus tying human and animal work together much more closely. Zola-Morgan & Squire J. Neuroscience, 7, 370-380,1987.

TITLE: Functional Anatomy of Neocortical-Hippocampal Circuits

PI: Timothy J. Teyler
Northeastern Ohio University
Neurobiology Program
(216) 325-2511

R&T PROJECT CODE: 4426017 CONTRACT NO: N0001486K0664

CURRENT END DATE: 31 JUL 1989

Technical Objective: The goal of the series of experiments is to delineate the nature of the neocortical to hippocampal (and vice versa) communication, to determine their topological parameters and ability to elicit long term potentiation at the level of the hippocampus. The objective is theory-driven and involves understanding how experiential information is processed in a massively parallel fashion.

Approach: Electrophysiological studies will determine the functional relationship between neocortex and hippocampus and will be complemented by plasticity studies wherein tetanic stimulation will be applied to the neocortical locus to determine if LTP is produced in hippocampus. Neuroanatomical research will be used to validate the neurophysiological studies.

Progress: Preliminary work determining the topography of the neocortical influence has been recorded from dentate, CA1, CA3 (hippocampus). (Teyler, T. & DiScenna, P., Ann. Rev. of Neuroscience, 1987, 10, 131-161.) A critical time period in the developing rat cortex for the demonstration of Long Term Potentiation has also been described. (Perkins & Teyler, Dev. Brain Res., in press).

TITLE: A Biological Neural Network Analysis of Learning and Memory

PI: Richard F. Thompson
University of Southern California
Psychology
(213) 743-2240

R&T PROJECT CODE: 4426001 CONTRACT NO: N0001488K0112

CURRENT END DATE: 31 JAN 1991

Technical Objective: A three year research plan includes three levels of complexity with- in which the PI plans to model the critical neuronal circuitry; each level builds cumulatively on the previous levels. Level I concentrates on single pathway models of conditioning involving the IO, deep nuclei, and other brain structures. These models will address phenomena at a trial-level of detail comparable to the Rescorla-Wagner model. Level II integrates level I into real-time models of conditioning which address effects of ISI manipulations and adaptive delay of the CR. Level III incorporates the previous levels into multiple-pathway models involving more complete descriptions of the stimulus-response pathways.

Approach: Approach involves a detailed empirical characterization of the prop- erties of the essential neurobiological network and a quantitative computational modeling of the network that incorporates all the known properties and constraints of the actual biological network. At the behavioral level the PI has adopted the Rescorla-Wagner (1972) model, an influential mathematical model of associative learning. At the biologi- cal level, the neural system shown to be responsible for the production of the classically conditioned nictitating membrane response will pro- vide the experimental test bed.

Progress: This contract is new in FY1988.

BIOLOGICAL INTELLIGENCE

CLUSTER 12

CHEMICAL MODULATORS OF INFORMATION PROCESSING

TITLE: Neuroregulators and Stress:Effects of Neuropeptides & Their Analogues

PI: Jack D. Barchas
Leland Stanford Junior University
Psychiatry
(415) 723-7522

R&T PROJECT CODE: 4426750 CONTRACT NO: N0001486K0251

CURRENT END DATE: 28 FEB 1989

Technical Objective: Operational situations expose Navy and Marine Corps personnel to stressors varying in severity. The body's response involves biochemical and physiological mechanisms not completely understood. This research will explore the role of neuropeptides in the stress response.

Approach: To perform a series of experiments to determine chemical and pharmacological properties of novel neuropeptides which have the C-terminal amide structure. Work will focus on peptide HI, searching for sequence related agonists and antagonists with a novel approach based on multiple solid phase peptide synthesis and radio receptor techniques.

Progress: In a series of studies on the peptide pancreastatin, RIA and immunohistochemical results indicate the presence of it or related peptides in the brain,pituitary,and adrenal, suggesting a possible neuroendocrine role for this peptide. Isolation of the gene is in progress after which studies of messenger RNA and peptide regulation can be performed.

TITLE: Experimental Investigations of Synaptic Learning Rules in the Cerebral Cortex

PI: Dr. Mark F. Bear
Brown University
Center for Neural Science
(401) 863-2070

R&T PROJECT CODE: 4426137 CONTRACT NO: Not yet assigned

CURRENT END DATE: 31 MAY 1991

Technical Objective: In the proposed experiments, the effects of high-frequency electrical stimulation of the white matter on the amplitude of cortical EP's will be studied as several parameters are varied systematically. In addition to manipulations of GABAergic inhibition, other parameters of interest will be the presence or absence of the modulatory substances acetylcholine and norepinephrine, the relative effectiveness of NMDA and non-NMDA receptors, and the effects of prior visual deprivation. The objective of these experiments is to formulate a set of rules that govern whether a burst of presynaptic activity leads to a lasting increase or decrease in synaptic strength. These rules can then be compared with the extant theoretical models of network modification.

Approach: Synaptic modifications have been observed directly in the developing visual cortex of behaving kittens. Critical variables appear to be the presence or absence of extrathalamic modulatory inputs, the level of network inhibition, the amount of stimulus-driven excitatory presynaptic activity, the concurrent level of evoked post-synaptic depolarization, and the recent history of neuronal activity. In the proposed experiments, a reduced preparation of the visual cortex, the in vitro brain slice, will be used to elucidate the precise contributions of each of these variables.

Progress: This contract is new in FY1988.

TITLE: Probing The Molecular Mechanisms of Associative Learning with Monoclonal Antibodies

PI: John F. Disterhoft
Northwestern University
Department of Cell Biology & Anatomy
(312) 908-7982

R&T PROJECT CODE: 4426134 CONTRACT NO: N0001488K0399

CURRENT END DATE: 30 JUN 1991

Technical Objective: The Technical objective is to learn more about the macromolecules that modulate the electrophysiological state and function of neurons. In collaboration with another contract (Moskal/Einstein) the PI will help produce and test a series of monoclonal antibodies which may be ideal probes that can both perturn function and identify the macromolecules normally involve in that function. The PI's testing will include both in vivo (LTP in hippocampal slices) and in vitro (behavioral classical conditioning) preparations.

Approach: The PI will evaluate the behavioral effect of antibodies on hippocampal neurons in the behaving animal and in brain slices. Intracellular recordings will be made in hippocampal sections to biophysically evaluate the effect of each monoclonal antibody on resting activity and excitability of the cells. In awake animals, the effect of various monoclonal during acquisition of a conditioned response will be observed.

Progress: This contract is new in FY1988.

TITLE: Stress-related neuroendocrine systems and information retrieval

PI: Paul E. Gold
University of Virginia
Psychology
(804) 924-0685

R&T PROJECT CODE: 4426625 CONTRACT NO: N0001485K0472

CURRENT END DATE: 28 FEB 1988

Technical Objective: This investigator will test the hypothesis that stress related hormonal states that exist during the acquisition and storage of new information are related to the hormonal states present when the organism (man or animal) requires that the information now be retrieved. The PI will attempt to determine the neurobiological bases for the observation that stress can be either beneficial or detrimental on the process of information storage and retrieval.

Approach: The approach is to address three general issues. These include the questions of whether epinephrine might regulate memory retrieval processes; whether cues for "learned fear" might interfere with the performance of learned responses because of the hormonal concomitants of the fearful cue; and whether the rules which relate neuroendocrine activity to memory retrieval might also be effective in regulating "retrieval" processes in a neurophysiological analog of memory (i.e., long-term potentiation).

Progress: Glucose injections enhance memory (Gold,1986). The dose response curve is an inverted-U, as it is for epinephrine, and the effects on memory are time-dependent. Adrenergic antagonists administered prior to training and treatment do not attenuate the effects of glucose on memory (Gold, Vogt, and Hall,1986)Plasma glucose levels show comparable increases after high shock training, as well as after injections of optimal memory enhancing doses of epinephrine or glucose (Hall and Gold, 1986).

TITLE: Functional Organization of Peptides in the Basal Ganglia

PI: Philip M. Groves
The Regents of the University of California
Psychiatry
(619) 452-3736

R&T PROJECT CODE: 4426637 CONTRACT NO: N0001485K0699

CURRENT END DATE: 31 AUG 1988

Technical Objective: The experiments are directed towards resolving several major issues regarding the mechanisms by which the basal ganglia and related cell groups of the subcortical motor system execute willed movement, including, for example, directed movements of the limbs toward specific targets, saccadic movements of the eyes, and certain aspects of posture and coordination in the vigilant, human observer.

Approach: Approach is to use 3D images of synaptic arrangements made by dopaminergic afferents to explore the intrinsic ultrastructure of the "motor" thalamus, a region of major confluence of cerebellar, basal ganglia and cortical motor information. The work is driven by a theory which suggests that the "motor" thalamus is disinhibited by the neostriatum and that his disinhibition lease to activation of motor cortex and then to movement.

Progress: Three-D organization of the immunoreactive peptide enkephalin in the caudate nucleus has been described (Groves et al J. Neuroscience, 1987, in press). Single projecting neurones of the ventral thalamic nuclei responsible for the translation of basal ganglia (Caudate) onto the cerebral motor cortex have been recorded intracellularly while stimulating afferents labelled with HRP. The HRP tracings have been followed with light and EM techniques.

TITLE: Actions of TYR-MIF-1 and MIF-1 as Opiate Antagonists

PI: A J. Kastin
Tulane University
School of Medicine
(504) 568-0811

R&T PROJECT CODE: 4426589 CONTRACT NO: N0001483K0262

CURRENT END DATE: 30 MAR 1988

Technical Objective: Naturally occurring neuropeptides are being identified with increasing frequency. Their physiological and behavioral effects are varied and not known completely. Identification of these actions during exposure to noxious or stressful stimuli, and their effect on learning may well lead to intervention techniques to reduce stress reactions, or improve learning ability in naval or Marine Corps personnel.

Approach: A series of experiments will be performed to identify the physiological and behavioral effects of endogenous neuropeptides with particular emphasis on their role in response to painful stimuli, as opiate antagonists, in learning situations, and in reversing shock.

Progress: Tyr-MIF-1 was shown to be part of an endogenous antiopiate neuronetwork that functions to balance the opiate system,in part by selective binding to the mu receptor site. Diurnal rhythms were lowest between 0800 to 1200 in both blood and brain and was reduced after exposure to constant light for 7 to 14 days. Brain capillaries may be the site of transport across the blood brain barrier.

TITLE: The Role of Lamination in Neocortical Function

PI: Harvey J. Karten
University of California, San Diego
School of Medicine
(619) 534-4938

R&T PROJECT CODE: 4426131 CONTRACT NO: Not yet assigned

CURRENT END DATE: 31 MAY 1991

Technical Objective: A major goal of this project is to investigate the nature and benefits of lamination of cortex. In the avain brain, cortical equivalent populations ("clonal clusters") of neurons occur in non- laminated configurations, but have similar characteristics in their connections, transmitters and cell morphology. The clonal nature of the avain telencephalon lends itself to both physiological and biochemical analyses not readily accomplished with mammalian neocortex. In the proposed experiments, the PI will collect detailed information about the clonal type of organization, particularly, within the avain visual system.

Approach: (1) The anterograde and retrograde transport of several tracers will be used to explore the microcircuitry of cortical equivalent neurons in the absence of lamination. (2) The transmitters/peptides/receptors in these cortical equivalent populations will be studied using immunochemistry and in situ hybridization histochemistry. (3) The morphological characteristics of neurons in these populations will be studied using the single-cell filling technique.

Progress: This contract is new in FY1988.

TITLE: Biochemistry of Drosophila Learning Mutants

PI: Margaret S. Livingstone
Harvard College
Neurobiology
(617) 732-1664

R&T PROJECT CODE: 4426811 CONTRACT NO: N0001486K0132

CURRENT END DATE: 31 OCT 1988

Technical Objective: Genetic and immunologic techniques will be used to study a particular Drosophila mutant that affects adenylate cyclase. In addition, monamine receptors, calcium-dependent protein kinase, cyclic AMP-dependent protein kinase, and opiate receptors are other proteins that will be manipulated by cloning the structural gene for that particular protein.

Approach: Using immunological techniques, the PI will try to show that several separate, parallel pathways that analyze visual information are immunologically distinct.

Progress: In Drosophila, cloning of the gene which causes selective loss of associative learning is underway. A start point in the appropriate region of the genome has been identified for future linking when the entire region is mapped.

TITLE: Analysis of neural systems involved in modulation of memory storage.

PI: James L. McGaugh
University of California, Irvine
Department of Psychobiology
(714) 856-5401

R&T PROJECT CODE: 4426815 CONTRACT NO: N0001487K0518

CURRENT END DATE: 31 DEC 1990

Technical Objective: The objective is to increase understanding of the brain systems involved in the processing of newly acquired information, and of the key brain structures and processes underlying the modulation of memory storage.

Approach: NMDA-induced lesions in specific nuclei in the amygdata will be performed to determine the specific brain regions and neurotransmitters involved in the modulation of memory storage.

Progress: Experimental work is proceeding on schedule with recently hired personnel and newly purchased equipment.

TITLE: Learning and Memory Enhancement by Neuropeptides

PI: Rita B. Messing
University of Minnesota
Department of Pharmacology
(612) 625-5960

R&T PROJECT CODE: 4411018 CONTRACT NO: N0001486K0407

CURRENT END DATE: 30 JUN 1989

Technical Objective: Organotins are found throughout the environment, but as yet little is known about the mechanisms by which they exert their toxic efforts on man- or about possible treatment. They are of great interest to the Navy since organotins are a major active component of anti-fouling agents. The technical objective of this program is to better understand their mechanism of action in producing human cognitive dysfunction.

Approach: Because trimethyltin (TMT) produces relatively specific, dose-related damage, rats treated with TMT are a useful model system for assessing cognitive, and related biochemical effects of varying degrees of pathology in hippocampus and related structures. To assess learning/memory impairment in TMT-treated rats, the P.I. uses a delayed reinforcement autoshaping procedure which incorporates features of both classical and operant conditioning paradigms.

Progress: The PI has completed initial dose-response study of effects of TMT on autoshaping and has submitted a paper that separates "non-specific" behavioral changes which may affect behavior of toxicant-exposed rats in assays of learning or memory from specific cognitive effects of the compound. Essentially, TMT interferes with complex (more cognitive?) rather than easy tasks.

TITLE: Probing the Molecular Mechanisms of Associative Learning with Monoclonal Antibodies

PI: Joseph R. Moskal
Albert Einstein College of Medicine
Neurosurgery
(212) 920-4328

R&T PROJECT CODE: 4426133 CONTRACT NO: Not yet assigned

CURRENT END DATE: 30 JUN 1991

Technical Objective: The first objective is to generate anti-hippocampal antibodies and evaluate their effect on trace eyeblink conditioning. The second objective is to generate new monoclonal antibodies that will be useful probes to continue to study structure-function relationships between cell-surface macromolecules and synaptic plasticity.

Approach: The PI has chosen three sources of immunogens in order to generate three new panels of antibodies. These will be; 1) freshly micropunched CA1 form adult rabbit hippocampus, 2) membranes from synaptosomes prepared from CA1 of trace-conditioned rabbits, and 3) a phosphorylated glycoprotein fraction obtained from synaptic membranes isolated from the CA1 of trace-conditioned rabbits.

Upon generation of each panel of antibodies, screening will be performed in order to identify those monoclonals that are IgG's and recognize characterizable, cell-surface antigens, found on hippocampal neurons. These antibodies will then be evaluated behaviorally and neurophysiologically by a colleague at Northwestern.

Progress: This contract is new in FY1988.

TITLE: Analysis of Synaptic Transmission Mediated by Peptides

PI: John G. Nicholls
University of Basel
Biocenter
Switzerland

R&T PROJECT CODE: 4426011 CONTRACT NO: N00014860044

CURRENT END DATE: 28 FEB 1988

Technical Objective: The principal aims of the experiments proposed are to study how the membrane potential of the presynaptic terminal and calcium entry influences release of peptide and whether the peptide transmitter is released in multimolecular packets or quanta, to ask if facilitation of release occurs so that in a train of action potentials each impulse releases more than the previous one, and to determine if the peptide acts back upon the terminals from which it is released.

Approach: For the analysis of peptide mediated transmission studies will be made on synapses formed in culture between identified nerve cells of known function containing peptide transmitters dissected out of the central nervous system of the leach. Transmission will be analyzed by recording electrically from pre- and postsynaptic cells with and without voltage and patch clamp. In addition electronmicroscopic studies and antibody techniques will be used to localize and identify transmitters in presynaptic terminals.

Progress: The ganglia cells have been cultured and show appropriate neuropeptide production. Peptide analysis and investigation of calcium related release mechanisms are underway.

TITLE: Assessment of Morphological and Physiological Correlates of Acetylcholine & VIP in Cerebral Cortex

PI: William E. Thomas
Meharry Medical College
Dept of Physiology
(615) 327-6288

R&T PROJECT CODE: 4426022 CONTRACT NO: N0001486K0488

CURRENT END DATE: 31 JUL 1989

Technical Objective: To provide insight into the synaptic functions of ACh/VIP colocalization and to elucidate the role of this interaction in cerebral cortex function.

Approach: Cholinergic and VIP-containing neurons will be identified in cortical-cell cultures by immunohistochemical staining for choline acetyltransferase (ChAT) and VIP. The proportion and morphological features of each neurochemical group will be determined separately; then colocalization of the two transmitters will be assessed by dual staining. Synaptic mechanisms of ACh/VIP neurons will be investigated by recording from postsynaptic neurons while stimulating ACh/VIP cells under various parameters.

Progress: During the first 6 months of the contract, equipment has been purchased and set up. Morphology of AChase containing neurones in primary cultures of dissociated rat cerebral cortex has been described.

(Note: Cofunded by Historical Black College Council.)

BIOLOGICAL INTELLIGENCE

CLUSTER 13

NEURAL PROCESSING OF SENSORY INFORMATION

TITLE: Theoretical and experimental research into biological mechanisms underlying learning and memory

PI: Leon N. Cooper
Brown University
Center for Neural Science
(401) 863-2585

R&T PROJECT CODE: 442b466 CONTRACT NO: N0001486K0041

CURRENT END DATE: 31 DEC 1987

Technical Objective: The major objectives of this research are (1) to elucidate the biological mechanisms that underlie learning and memory, and (2) to discover principles of organization that can account both for the experimental data on the cellular level and, when applied to large numbers of neurons that receive sensory and/or interneuronal information, for various higher system properties, including abstraction, feature analysis, categorization, and language acquisition.

Approach: Experiments will be conducted to test and elaborate the PI's model of synaptic modification during learning. Subjects will be kittens that have been visually deprived in various ways, and then subjected to electrophysiological and neuroanatomical analysis to assess that effects of the deprivation on the responsivity and selectivity of individual cells in striate cortex. The results of this analysis will be used to elaborate a theory of neural network modification during learning. The resulting conception will be used as the basis of computer simulations of human performance in complex learning and memory tasks such as the acquisition of language.

Progress: In the past contract period the PI has made progress in both theory and experiment. His theory of synaptic modification has been extended to incorporate more realistic anatomical networks and these complex networks have been approximated in a very illumirating fashion.

TITLE: Neural Network Models for Parallel Visual Processing

PI: George L. Gerstein
University of Pennsylvania
Dept of Physiology
(215) 898-8752

R&T PROJECT CODE: 4426825 CONTRACT NO: N0001487K0766

CURRENT END DATE: 31 AUG 1988

Technical Objective: Computational rules are being defined from computer vision algorithms whose overall output replicates human psychophysical performance in preattention scene segmentation. The research proposed here is the investigation of neural not models capable of performing the same computations as the computer vision algorithms. The development of such models is essential to further neurobiological studies and machine architecture development.

Approach: To construct and simulate networks of neuronal assemblies which are capable of performing a class of visual computations that deal with texture. The network formalism is influenced and constrained by an area of mathematics describing Gabor filters and neurophysiological data derived from experiments on the mammalian visual system.

Progress: Money has been in place for six months. The graphics workstation is in the lab and operating. A new post-doctoral research fellow has been hired.

TITLE: Cortical Processing of Visual Information

PI: David H. Hubel
Harvard University
Neurobiology
(617) 732-1655

R&T PROJECT CODE: 4426631 CONTRACT NO: N0001485K0447

CURRENT END DATE: 30 JUN 1988

Technical Objective: This investigator will test whether the apparent depth of an object is partially computed from the disparities of the images of a number of objects in the visual stimulus. Tis will provide a first step in learning which algorithm(s) the brain employs to detect depth of visual field. In collaboration with others, the PI will use this algorithm(s) in machines designed to process visual information.

Approach: The approach involves the following research strategies: Single cell recording from visual cortex as the retina is being stimulated in a precise fashion. Histological verification of actual cell recorded from using a number of techniques including cytochrome oxidase, nissl stain, 2-deoxyglucose autoradiography, HRP, etc. Visual stimuli generation is controlled by computer manipulation of TV monitors, prisms, and polarizers.

Progress: Data from monkeys suggest that analysis of visual form,color, movement and depth are carried out by three or four separate & independent pathways. Similar pathways are suggested in humans.

TITLE: Physiology, Anatomy, and Psychophysics of Parallel Processing in the Primate Visual Cortex.

PI: David H. Hubel
Harvard College
Physiology
(617) 732-1655

R&T PROJECT CODE: 442g003 CONTRACT NO: N0001488K0200

CURRENT END DATE: 30 JUN 1991

Technical Objective: The first objective is to examine differences in responses between cortical layers in order to learn more about the transformation of information. The second objective is a detailed analysis of single cell properties in Visual Areas 1 and 2 as predicted from psychophysical experiments. The third objective is to continue studying the intrinsic connectivity among the three kinds of stripes in Visual Area 2. The fourth objective is to use voltage sensitive dyes to examine cortical column geometry in Visual Areas 1 and 2.

Approach: To use anatomical tracer studies, physiological recordings, 2-deoxyglucose autoradiography and voltage-sensitive dyes to more clearly define which visual functions might be processed by each anatomically defined subsystem and to use psychophysical studies to explore how human visual perception correlates with the segregation and parallel processing seen in the physiological and anatomical studies in other primates.

Progress: This contract is new in FY1988.

TITLE: Seeing Pattern From Motion

PI: William T. Newsome
State University of New York
Neurobiology & Behavior
(516) 632-8628

R&T PROJECT CODE: 442g001 CONTRACT NO: N0001488K0161

CURRENT END DATE: 30 NOV 1990

Technical Objective: Objective is to generate experimental evidence from cortical neuron activity that both tests and elaborates a computational theory of visual motion analysis.

Approach: The approach entails microelectrode recording from neurons in cortical areas MT and MST of alert monkeys viewing controlled visual patterns. The stimulus variations will be revealed in differential responses of cells tuned to component motion, pattern motion, and discontinuities in moving images.

Progress: This contract is new in FY1988.

TITLE: Control of Biosonar behavior by the Auditory Cortex

PI: Nobuo Suga
Washington University
Biology Department
(313) 889-6805

R&T PROJECT CODE: 4426812 CONTRACT NO: N0001487RM24018

CURRENT END DATE: 31 DEC 1989

Technical Objective: The objectives are (1) to use lesion techniques to validate physiological analyses of the neural substrate of bat biosonar capabilities, and (2) to identify the neural substrate of bat hyperacuity.

Approach: Bats will be trained to carry out a variety of echolocation tasks, and then will be subjected systematically to lesions in physiologically identified brain regions believed responsible for various aspects of echolocation behavior. The effects of the lesions on performance will be studied.

Progress: Major equipment items have been procured, programming and set-up of new experimental system are underway.

Outside Funding: AFOSR (partial)

TITLE: Adaptive information processing in Auditory Cortex

PI: Norman M. Weinberger
University of California, Irvine
Center for Neurobiology of Learning and Memory
(714) 856-5512

R&T PROJECT CODE: 4426805 CONTRACT NO: N0001487K0433

CURRENT END DATE: 31 MAY 1990

Technical Objective: The PI will test working hypotheses regarding putative principles of adaptive information processing in sensory cortex by obtaining neurophysiological data simultaneously from more than one neuron via an on-line objective waveform-sorting algorithm. Data will be obtained from various auditory cortical fields, various cortical lamina, and from neighboring neurons to elucidate parallel processing, regional specificity of plasticity, and local circuit plasticity, respectively. Standard conditioning, discrimination and discrimination reversal, and contextual control of the conditioned response will all be employed in order to provide critical data concerning acquisition and storage of information. This program of research emphasizes the fundamental requirement that an understanding of adaptive information coding and storage must account for both the physical and the psychological parameters of stimuli. The studies proposed herein should provide foundational data on biological intelligence as expressed by adaptive information processing in neocortex.

Approach: The frequency tuning of single neurons will be determined immediately before and after various stages of training in classical conditioning paradigms using pure tone as the conditioned stimulus and rewarding stimulation of the hypothalamus as the unconditioned stimulus. Independent behavioral indices of learning will be obtained by quantification of the pupillary dilation conditioned response.

Progress: This contract is new in FY1988.

TITLE: Committee on Hearing, Bioacoustics and Biomechanics

PI: M A. Whitcomb
National Academy of Sciences
National Research Council
(202) 334-3022

R&T PROJECT CODE: 4426124 CONTRACT NO: N0001487G0342

CURRENT END DATE: 28 FEB 1989

Technical Objective: Provide information on current and anticipated problems relevant to Navy and other federal agencies in the areas of hearing, bioacoustics, and biomechanics.

Approach: Working groups will be formed to address specific issues identified by a sponsor. Each group will be made up of leading experts in scientific fields relevant and specific to the problem at hand, and will produce a document responsive to problem solution.

Progress: Recent activity was concerned with research on hearing loss resulting from exposure to a variety of noise sources such as impulsive, impact, continuous, and intermittent, and the interactions of each with one another and with various environmental conditions as they contribute to hearing loss.

Outside Funding: Completely funded by AFOSR, NIA, NSA, AFMCB, NMRDC, AMRDC, NSF, and NASA.

TITLE: Committee on Vision

PI: P Ebert-Flattau
National Academy of Sciences
National Research Council
(202) 334-2565

R&T PROJECT CODE: 4426125 CONTRACT NO: N0001487K0345

CURRENT END DATE: 28 FEB 1989

Technical Objective: Provide information on current and anticipated problems relevant to Navy and other federal agencies in the areas of vision, visual standards, and hazards to vision.

Approach: Working groups will be formed to address specific issues identified by a sponsor. Each group will be made up of leading experts in scientific fields relevant and specific to the problem at hand, and will produce a document responsive to problem solution.

Progress: The symposium on Frontiers of Visual Science addressed the topic of modularity of vision; a report is in preparation. Working groups on Aging Workers and Visual Impairment, Night Vision, and Myopia Prevalence and Progression met, reports are in progress.

Outside Funding: Completely funded by NMRDC, AMRDC, NSF, NIA, AFMCB, NEI, VA, and NASA.

BIOLOGICAL INTELLIGENCE

CLUSTER 14

LOCAL NEURAL CIRCUIT INTERACTIONS

TITLE: Neural Circuitry of Behavior as a Substrate for Information Processing: A Developmental Analysis in Aplysia

PI: Thomas J. Carew
Yale University
Department of Psychology
(203) 432-4675

R&T PROJECT CODE: 4426801 CONTRACT NO: N0001487K0381

CURRENT END DATE: 31 MAR 1990

Technical Objective: Three specific questions will be addressed, each at a BEHAVIORAL and a CELLULAR level of analysis: 1) How are neural networks for specific behavioral responses assembled and activated during development? 2) How are independent networks interconnected during development to produce integrated complex behavioral sequences? and 3) How are these integrated networks modulated by experience and learning?

Approach: The marine mollusk Aplysia californica has proven to be an extremely useful preparation for the analysis of the role of identified neurons and neural circuits in behavior and learning. The primary goal of this research is to use development in Aplysia as an analytic tool to examine the way specific neural circuits acquire the capacity for information processing. A broad range of different defensive behaviors will be examined to permit establishing principles of neuronal organization unique to particular types of response systems on the one hand, and to principles of general significance on the other. These behaviors will include: 1) graded reflexes (the gill withdrawal reflex and the tail withdrawal reflex); 2) an all-or-none response (the inking response); and 3) a cyclical behavior (escape locomotion).

Progress: Equipment has been bought, a new post-doctoral fellow hired, and recordings from various cells in developing aplysia ganglia are being analyzed.

TITLE: Synapse-Specific Facilitation During Learning and Memory

PI: Gregory A. Clark
Columbia University
Research Foundation for Mental Hygiene
(212) 960-2237

R&T PROJECT CODE: 4426820 CONTRACT NO: N0001487K0526

CURRENT END DATE: 14 JUN 1990

Technical Objective: To determine whether long-term as well as short-term facilitation can be synaptic specific and then to define the underlying cellular mechanism (e.g. is new protein synthesis required, are new proteins used selectively?) To investigate a possible physiological and behavioral role for synapse-specific facilitation, that is, as a neural mechanism for response specificity in classical conditioning of the siphon-withdrawal response in Aplysia.

Approach: Despite substantial progress in the neurobiology of learning, a fundamental question still remains concerning the basic unit of information storage in the nervous system. Does learning occur at the level of individual cells, or instead at the level of individual synapses? Stated another way, must plasticity occur at all synapses of a given cell, so that it modifies transmission at connections onto all of its postsynaptic targets? Or alternatively, is it possible to enhance transmission at one set of terminals, without enhancing transmission at other terminals of the same cell? Because synapse-specific facilitation would enhance only selected outputs of a given cell, it would provide a high degree of precision in the modification of neural pathways, and consequently, in the modification of behavior. For these reasons, synapse-specific plasticity has been proposed to occur on the theoretical grounds and has been incorporated into a number of conceptual and computational models of learning in neural networks, as well as recent electrical circuit models (Hopfield and Tank, 1986). This work will test whether branch-synaptic facilitation occurs and what are the relevant parameters.

Progress: This contract is new in FY1988.

TITLE: Gordon Conference on Neural Plasticity.

PI: Alexander M. Cruishank
Gordon Research Conference
Gordon Conference Division
(305) 284-4117

R&T PROJECT CODE: 4426810 CONTRACT NO: N00014870200

CURRENT END DATE: 30 OCT 1987

Technical Objective: The objective of this procurement is to support a conference to facilitate discussion among neuroscientists working in diverse fields, yet concerned with the questions of how the CNS learns. More specifically, topics such as molecular aspects of synapses, immunological studies of neural development, specificity of neural connections, and ion channels and signal transduction will be discussed.

Approach: Discussions among neuroimmunologists, neurochemists, cell biologists, and other scientists whose work emphasizes a dynamic approach to studying the nervous system will be fostered by convening a Gordon Conference on this topic. The participants are leaders in their respective fields, and an open forum for ideas will be provided. Participants will be limited to approximately 100 individuals. Selection will be based on the contribution the attendee may make toward the success of the meeting, as well as the meetings potential benefit to his/her own research interests.

Progress: No report on this meeting has been received yet.

TITLE: Interneuronal Information Processing

PI: Daniel Gardner
Cornell University
Dept of Physiology
(212) 472-6669

R&T PROJECT CODE: 4426021 CONTRACT NO: N0001486K0491

CURRENT END DATE: 30 NOV 1989

Technical Objective: Project will identify, characterize types of functional elements available to an actual neural network, the ways in which they are combined, and the functional consequences of their use. The goal is both a generalizable biophysical description of synapses and an understanding of the role of the synapses in the adaptive behavior of a cell and network. Specific questions to be asked include: Do individual neurons act as adaptive elements, maximizing variance of their membrane potential? Is synaptic potential amplitude more plastic than its duration? What are the relative contributions of multiple-component synaptic potentials and direct/indirect synaptic information to adaptive networks.

Approach: This work will investigate and characterize the types of functional elements available to an actual neural (invertebrate, aplysia) network, the ways in which they are combined, and the functional consequences of their use. The goal is both a generalizable biophysical description of synapses and an understanding of the role of the synapses in the adaptive behavior of a cell and network.

Progress: A gate noise generator was designed and built to reproducibly increase membrane potential and current variance of individual aplysia neurons under voltage clamp. Three major protocols were designed to test the hypothesis that membrane potential variance can adaptively alter synaptic strengths. The first series, interspersing noise and evoked postsynaptic currents using paired postsynaptic neurons as controls, is nearly complete and shows no non-associative effects of the noise. Results were recently published (J. Neurophysiol . 56, 1424-1438, 1986.).

Outside Funding: AFOSR (partial)

TITLE: International Conference on Gap Junctions

PI: Ross G. Johnson
University of Minnesota
Department of Genetics and Cell Biology
(612) 624-1741

R&T PROJECT CODE: 4426800 CONTRACT NO: N0001487G0074

CURRENT END DATE: 30 APR 1988

Technical Objective: Understanding cell-to-cell communication requires comprehension of the structure and function of the involved processes: One such process is the gap junction. This information may increase understanding neural plasticity and provide suggestions for alternate hardware architectures.

Approach: The conference is being organized by the principal investigator aided by an international organizing committee. The meeting is being held at the Asilomar Conference Center, C A., and will consist of five daily sessions covering theoretical and experimental aspects.

Progress: Conference was held as planned. A report is being prepared.

TITLE: Mechanisms of pattern generation in complex biological systems.

PI: SCOTT J. KELSO
Florida Atlantic University
Center for Complex Systems
(305) 338-2230

R&T PROJECT CODE: 4426807 CONTRACT NO: N0001487G0156

CURRENT END DATE: 15 APR 1989

Technical Objective: The objective is to develop a mathematical characterization of the dynamical properties of complex motor systems. This characterization will be based on synergetics, a physical theory for the spontaneous formation of pattern in open, nonequilibrium systems.

Approach: The approach combines physicists, psychologists and neuroscientists toward the goal of formally characterizing the neural determinants of coordinated motor behavior. The effort entails the acquisition of neurophysiological data from behaving molluscs and behavioral data from humans. These data will be characterized in terms of the collective variable constituents of synergetics.

Progress: Using attractor dynamics, the PI has been able to model the motor system phenomena of stability under perturbation and synchronization. Efforts are currently underway to test the models, using data obtained from the mollusc Helisoma.

Outside Funding: Completely cofunded by Physics (ONR Code 1112) and AFOSR.

TITLE: Meeting on cellular neurobiology

PI: Kenneth J. Muller
Marine Biological Laboratory
Dept. of Physiology and Biophysics
(305) 547-5963

R&T PROJECT CODE: 4426826 CONTRACT NO: N0001487G0243

CURRENT END DATE: 01 JAN 1988

Technical Objective: The objective is to hold a meeting bringing together investigators of considerable influence in the field of systems neurobiology. Their expertise will blend such seemingly diverse areas as development, behavior, neurotransmitters and receptors, membrane biophysics, regeneration, and neural modelling of oscillators.

Approach: The Marine Biological Laboratory at Wood's Hole (MBL) is a particularly suitable location for the meeting for several reasons. It has ideal housing and meeting room facilities and a large summer population of Neuroscientists who otherwise might not be able to attend such a meeting. MBL has a tradition of open, critical exchange of ideas that has both provided crucial training for each generation of neurobiologists and has paved the way for new avenues of research.

Progress: Not Applicable.

TITLE: Second IEEE/ONR Conference on Synthetic Microstructures in Biological Research

PI: Martin Peckerar
Naval Research Laboratory
Microelectronics Processing Facility
(202) 767-3150

R&T PROJECT CODE: 4426135 CONTRACT NO: N0001488WX24212

CURRENT END DATE: 30 SEP 1988

Technical Objective: To support a conference bringing together leaders in neurobiology, and microstructure fabrication to discuss new developments in the area of synthetic microstructures as they may be relevant to sensing and recording neural activity, and subsequent development of artificial neural systems.

Approach: Discussion among neurobiologists, physicists, and leaders in the field of microstructure fabrication and technology will be fostered by this conference.

Progress: Not applicable.

TITLE: Experimental Data Base Generation for Computational Modelling

PI: Allen I. Selverston
University of California, San Diego
Neuroscience Department
(619) 534-2672

R&T PROJECT CODE: 4426128 CONTRACT NO: N0001488K0328

CURRENT END DATE: 31 MAY 1991

Technical Objective: The goals of the proposed research are to obtain physiological data from an invertebrate nervous systems which can be used to support the development of new computational models of neural functioning. These can serve as the basis for pattern recognition and motor control algorithms. Data will be obtained relating the various conductances present in single neurons to their individual information handling capabilities. Additional information will be obtained on synaptic and network properties which could be used in modelling the system. As data is obtained, it will be incorporated into new computational models which will then be tested with experimental preparations.

Approach: The model consists of only thirty neurons yet generates two complex output patterns. Moreover, these neurons are individually identifiable -- that is , each is characterized by particular properties which are invariant from one animal to the next -- and their pattern of synaptic connectivity is stereotyped and well characterized. It is easy to record intracellular potentials in these neurons, including synaptic potentials. The behavior of the entire system can be altered by injecting current into single cells or by the application of various neuromodulators which alter synaptic strengths. This model system is perhaps the best understood pattern generator, and is well suited to a quantitative analysis.

Progress: This contract is new in FY1988.

TITLE: Dendritic Properties and Neural Networks

PI: Gordon M. Sheperd
Yale University
Department of Neuroanatomy
(203) 785-4336

R&T PROJECT CODE: 4426007 CONTRACT NO: N0001486K0145

CURRENT END DATE: 31 DEC 1988

Technical Objective: The experiments and simulations are designed to construct nerve nets incorporating realistic dendritic properties. This should provide a better basis for applying network models to the analysis of human brain function, and give new insights into the neural basis of memory, perception, and other cognitive functions.

Approach: The main focus will be on the distal dendrites and dendritic spines in the cerebral cortex. Since these are currently beyond the limit of experimental methods, their properties will be analyzed using compartmental modelling techniques suggested by Rall. This involves the introduction of general electrical circuit analysis programs that can simulate any arbitrary branching pattern and distribution of functional properties such as passive properties, voltage-dependent conductances, and logic operations arising from interactions between excitable states. These models should characterize the contributions of branching patterns in dendrites to specific neuronal functions.

Progress: Simulations of interactions between distal dendritic spines with an excitable membrane have been carried out, using an electrical circuit analysis program for the compartmental representation of a dendrite and several spines. Interactions between responses to single and paired excitatory and inhibitory synaptic interactions have been analyzed to reveal basic logic operations (AND,OR,AND-NOT). Shepard & Brayton, Neuroscience, 21, 151-165, 1987.

TITLE: Computer Simulation of Neural Systems

PI: Thomas P. Vogl
Environmental Research Institute of Michigan

(703) 520-5250

R&T PROJECT CODE: 4426132 CONTRACT NO: Not yet assigned

CURRENT END DATE: 31 MAY 1991

Technical Objective: The technical objectives involve finding the answers to the following questions related to Dr. Alkon's model:

(1) What are the roles of presynaptic, postsynaptic, and intraneural time delays in biological network performance and stability? (2) Which features of the biologic system are essential for the memory/recognition process and which are phylogenetic detritus? (3) What are the qualitative and quantitative differences between long- and short-term memory? (4) What is the role of changes in the membrane potential curves (membrane polarization) in the learning process? (5) What are the respective roles of pan-neurons vs. circum-synaptic membrane changes in the learning and recall processes? (6) What is the role of interlayer, particularly next-nearest-neighbor layer, connections in the performance of neural nets?

Approach: Initially, efforts will focus on modelling the structure, neurochemistry, neurophysiology, and biophysics of the marine mollusc Hermissenda crassicornis with eventual extension to more complex, vertebrate systems. An essential feature of the proposed effort will be the close collaboration among neurophysiology and biophysics researchers at the National Institutes of Health (DHHS/NIH/NINCDS) and computer science and applied mathematics researchers at ERIM in all stages of the planning and execution of the research. To this end, ERIM scientists will have primary responsibility for the development of suitable computer models, while Dr. Alkon's group at NIH will perform the neuro- logical experimentation. Both groups will collaborate on the tasks of defining and realistic testing of the models.

Progress: This contract is new in FY1988.

BIOLOGICAL INTELLIGENCE

CLUSTER 15

MARINE MAMMALS

TITLE: Nutritional and Thermal Requirements of Marine Mammals

PI: Daniel P. Costa
University of California, Santa Cruz
Institute of Marine Sciences
(408) 429-2786

R&T PROJECT CODE: 4426702 CONTRACT NO: N0001487K0178

CURRENT END DATE: 31 JAN 1990

Technical Objective: This work unit addresses the maintenance requirements of captive dolphins and sea lions to establish criteria to assess nutritional status which in turn directly relates to animal health, an area of significant concern to Navy use of the animals.

Approach: Perform a series of experiments to quantify maintenance requirements of bottlenose dolphins and california sea lions and establish criteria to assess nutritional status, establish thermoneutral zones, and identify major routes of heat transfer.

Progress: Feeding and growth records on all marine mammals are recorded daily; animals weighed weekly. Food fish samples analyzed for fat, protein, ash, manganese, and water content. Blubber measures taken weekly using ultrasonic blubber depth determinations. Assimilation efficiency deter- mined from food and fecal samples.

TITLE: Cell Mediated Immunologic Defense Mechanisms of Dolphins

PI: Bradley Fenwick
Kansas State University
Department of Pathology
(913) 532-5634

R&T PROJECT CODE: 4426701 CONTRACT NO: N0001487K0215

CURRENT END DATE: 31 AUG 1991

Technical Objective: Maintaining dolphin health is important to effective use of these animals in executing selected Navy tasks. This work unit will investigate the role of normal and disordered immunoregulation in disease resistance.

Approach: Research will involve isolation,cloning and study of antigen specific T-lymphocytes from normal and immunized dolphins. Immune regulatory mechanisms will be studied by characterization of proliferative responses induced by various antigens in combination with interleukin-2 and primed macrophages.

Progress: Serum iron concentration was found to differentiate healthy from clinically ill dolphins; iron concentration was significantly reduced in stressed or ill dolphins. If confirmed, this finding will allow for the early identification of sub-clinically ill dolphins.

TITLE: Dynamics and Diagnostic Value of Plasma Indicators of Stress in Small Cetaceans

PI: D. J. Geraci
University of Guelph
Pathology
(519) 823-8800

R&T PROJECT CODE: 4426706 CONTRACT NO: N0001487J1279

CURRENT END DATE: 31 OCT 1989

Technical Objective: Marine mammal health is a continuing concern to Navy research and operations. This work unit investigates the interaction of stress, iron metabolism, and the immune system so as to understand the underlying dynamics of disease resistance.

Approach: Conduct experiments to establish dynamics and turnover of selected blood constituents in both healthy and diseased animals.

Progress: Literally thousands of specimens have been obtained and preserved; preliminary analysis is underway.

TITLE: Dolphin Hydrodynamics: Biopolymers and Flow Field

PI: Eric W. Hendricks
Naval Research Laboratory
Fluid Mechanics Branch
(202) 767-3888

R&T PROJECT CODE: 4426705 CONTRACT NO: N0001487WX24155

CURRENT END DATE: 30 SEP 1988

Technical Objective: Determination of the chemical composition and structure of naturally occurring biopolymers may permit synthesis of such polymers and possibly lead to improved drag reduction on naval vessels.

Approach: Analyze the secretion from glands around the eyes of dolphins using controlled chemical and enzymic degradation to determine peptide and carbohydrate subunits to identify linkages;determine molecular weight and chemical composition.

Progress: The main thrust of the computational efforts was devoted to the generation of a computational grid around a dolphin. A map of dolphin shape, based on information from NOSC HAWAII and from the Smithsonian was used as a starting point to generate a triangular surface grid, provide it with points that define the surface, join the points with lines, and join the lines to form surface patches, resulting in complete triangulation of the dolphin surface.

TITLE: Cognitive Processes and Characteristics of Bottlenose Dolphins

PI: Louis M. Herman
University of Hawaii
Kewalo Basin Marine Mammal Laboratory
(808) 538-0067

R&T PROJECT CODE: 4426613 CONTRACT NO: N0001485K0210

CURRENT END DATE: 30 SEP 1990

Technical Objective: The Navy currently uses marine mammals in a limited way. This work unit will explore the possibility of extending such use to more complex situations by means of acoustic and gestural symbols.

Approach: A series of experiments will be performed over a three year period to determine (1) the ability of the dolphin to understand sentences expressed in artificial acoustic and gestural languages and (2) the possibility that the dolphin has the capability to produce and exchange information using symbols.

Progress: Results show that dolphins can report to a trainer on the presence or absence of named objects in their tank in response to specific queries. A capability for representing and remembering three- dimensional real world objects was demonstrated. Two young dolphins captured from the wild have been acquired and initial training started.

TITLE: Representation in Dolphin Memory

PI: Paul E. Nachtigall
Naval Ocean Systems Center Detachment
Research Branch Code 512
(808) 257-5256

R&T PROJECT CODE: 4426900 CONTRACT NO: Not yet assigned

CURRENT END DATE: 30 DEC 1988

Technical Objective: This work unit addresses certain of the cognitive capabilities of the dolphin, with special emphasis on memory functions and representation of events in memory.

Approach: Perform a series of experiments to investigate the dolphin's ability to represent sequences of events (a) in an unstructured list, and (b) in a serially structured sequence.

Progress: This contract is new in FY1988.

TITLE: Dolphin Cognition: Sensory Perception, Rhythmic Patterning, and Cross-Model Transfer in the Bottlenosed Dolphin

PI: Kenneth S. Norris
University of California, Riverside
Long Marine Laboratory
(408) 429-2836

R&T PROJECT CODE: 4426704 CONTRACT NO: N0001487K0192

CURRENT END DATE: 31 OCT 1989

Technical Objective: Assessment of the cognitive importance of patterning of dolphin acoustic signal streams may provide insight into vocal communication among dolphins and provide a basis for development of new or improved training procedures of use to navy programs.

Approach: Experiments will investigate how and in what context dolphins rhythmically modulate their echolocation based message streams. This will include body scans,beam steering,and locomotion induced changes in the emitted signal stream.

Progress: Animals have beer acclimated to routine health related protocols, and have learned to respond to preliminary commands to be used in the investigation.

TITLE: Marine Mammal Cognitive Processes

PI: Ronald Schusterman
University of California, Santa Cruz
Long Marine Laboratory
(408) 429-4945

R&T PROJECT CODE: 4426614 CONTRACT NO: N0001485K0244

CURRENT END DATE: 31 DEC 1987

Technical Objective: The Navy currently uses marine mammals in a limited way. This work unit will explore the possibility of extending such use to more complex situations by means of acoustic and gestural symbols.

Approach: A series of experiments will be performed over a three year period to determine (1) the ability of the sea lion to understand sentences expressed in artificial acoustic and gestural languages and (2) the possibility that the sea lion has the capability to exchange information using symbolic responses.

Progress: Results show that sea lions can learn to respond correctly to objects designated large or small,and on transposition tests,correctly selected the larger of two otherwise identical objects when the now smaller item was previously the larger item. This strongly suggests that the adjectives had both an absolute and a relative meaning.

TITLE: Marine Mammal Health: The Interrelationship of Autochthonous Viruses and Stress

PI: Alvin W. Smith
Board of Higher Education on Behalf of Oregon College of Veterinary Medicine
(503) 754-2318

R&T PROJECT CODE: 4426703 CONTRACT NO: N0001487K0164

CURRENT END DATE: 31 JAN 1990

Technical Objective: To define more clearly the interrelationship of viral disease and stress and the decrement both impose on overall animal health,so as to improve the health and operational effectiveness of navy marine mammal systems.

Approach: Determine the stress status and viral profiles of healthy and sick marine mammals,focussing on developing assays for measuring the function of cellular immune component and changes therein resulting from stress or exposure to antigenic materials.

Progress: cDNA from genomic RNA of San Miguel Sea Lion virus has been synthesized,cloning is in process. Monoclonal antibodies to SMSV-5 have been developed and are being used to profile antigenic determinants of caliciviruses. A cetean calicivirus (CCV Tur-1) has been isolated and preliminary data suggest it may be hepatitis producing.

TITLE: Investigating the Development of Signature Whistles and Signature Labelling in Bottlenosed Dolphins

PI: Peter Tyack
Woods Hole Oceanographic Institution
Biology
(617) 548-1400

R&T PROJECT CODE: 4426700 CONTRACT NO: N0001487K0236

CURRENT END DATE: 31 JAN 1990

Technical Objective: This acceleration provides for data gathering on the vocal behavior of selected open water whales which may have relevance to sonar operations.

Approach: Research will involve reevaluation of bioacoustic data, comparison with new data, and participation in the Charleston field experiments.

Progress: Instrumentation has been purchased or built, data gathering arrangements have been made.

BIOLOGICAL INTELLIGENCE

CLUSTER 16

BEHAVIORAL IMMUNOLOGY

TITLE: Investigations of Stress Induced Alterations in Neutrophil Function

PI: Andrew S. Baum
Uniformed Services Univ of the Health Sciences
F. Edward Hebert School of Medicine
(202) 295-3270

R&T PROJECT CODE: 442d008 CONTRACT NO: N0001488WM24007

CURRENT END DATE: 31 OCT 1990

Technical Objective: This project will measure individual differences in the psychological effects elicited by a physically and emotionally demanding field training experience, and study how these effects relate to changes in endocrine and immune system activity. The goal is to better understand the mechanisms determining who gets ill under adverse conditions.

Approach: Medical students at Uniformed Services Universities of the Health Sciences, all of whom must undergo a MASH-like field training exercise, will be studied before, during, and after the experience. Data to be collected include measures of degree of stress experienced and a number of endocrine and immune system activity measures. PIs are partícularly interested in how endogenous opioids inter- act with neutrophil cells, and whether or not this interaction is affected by psychological status.

Progress: This contract is new in FY1988.

TITLE: Immunological Consequences of Social Stratification and Change.

PI: Christopher L. Coe
University of Wisconsin System
Department of Psychology
(608) 263-3550

R&T PROJECT CODE: 442d005 CONTRACT NO: N0001487K0227

CURRENT END DATE: 28 FEB 1990

Technical Objective: The primary goal is to assess how psychological and social factors affect immune competence in the individual. Immunological evaluations will explore the effects of recent and established social relationships, the formation and dissolution of such relationships, and the capacity of social relationships to buffer the individual during stressful challenge. Data will allow determination of which immune measures are most efficacious for this type of research, and will explore whether or not adrenal and gonadal hormones are important in the mediation of the immune changes observed.

Approach: Various measures of social behavior, hormonal activity, and immune function will be repeated over time. Within subject comparisons will provide information about constancy of the measures, and between subject comparisons will evaluate the effects of various social relationships and changes in social relationships, as operationalized in housing conditions (individual vs. pair-housing vs. housing in groups of four). Stressful challenge will be represented by exposure to an adult male stranger and to a female in heat, as well as by alterations in the normal light/dark cycle.

Progress: This contract is new in FY1988.

TITLE: Behavior, Immunologic Response, and Upper Respiratory Infection

PI: Sheldon Cohen
Carnegie-Mellon University
Dept. of Psychology
(412) 268-2336

R&T PROJECT CODE: 442d007 CONTRACT NO: NCC01488K0063

CURRENT END DATE: 31 DEC 1989

Technical Objective: The primary purpose of the proposed research is to determine the role of natural social support systems in individual susceptibility to respiratory infection and related symptomatic behavior. The work will also investigate the role of immunologic function in linking various behavioral measures to disease, and will test two alternative models of the support--illness relationship (social support as a buffer against stress and as a main effect).

Approach: In a prospective design approximately 1,050 healthy subjects are exposed to cold or influenza viruses (or to placebos), then quarantined for 5 days and carefully observed for illness outcomes. Subjects will be characterized on various psychosocial measures and immunologic assays before the trials begin, and these will be analyzed for their power to predict immunologic and illness outcomes.

Progress: This contract is new in FY1988.

TITLE: Vulnerability to Allergic Disorders in Families of Children with Behavioral Inhibition

PI: Jerome Kagan
Harvard College
Department of Psychology
(617) 495-3870

R&T PROJECT CODE: 442d006 CONTRACT NO: N0001488K0038

CURRENT END DATE: 31 MAY 1990

Technical Objective: The main purpose of this research is to determine if there is an association between the presence of the temperamental trait of behavioral inhibition to the unfamiliar in young children and susceptibility to allergic disorders in those children and their close relatives. A second purpose is to determine if an index of social anxiety (an adult analogue of behavioral inhibition) is associated with adult susceptibility to allergy.

Approach: A standard medical interview designed to assess the presence of allergic and other medical disorders will be administered to the parents, grandparents, aunts and uncles of inhibited and uninhibited children. In addition, the mothers of the children will be administered separate interview schedules for the child and the child's siblings. All the adults will be given a standard social anxiety scale to test for an association between susceptibility to allergy and social anxiety.

Progress: This contract is new in FY1988.

TITLE: Stress, Coping, and Illness

PI: Sandra M. Levy
University of Pittsburgh
Western Psychiatric Institute
(412) 647-6351

R&T PROJECT CODE: 442d003 CONTRACT NO: N0001487K0224

CURRENT END DATE: 28 FEB 1989

Technical Objective: The objectives are (1) to relate stressful life events to lymphocyte alteration and to incidence of infectious illness, and (2) to explore intermediate links in these relationships (psychological and biological).

Approach: This is a prospective study in which base-line measures will be followed by repeated measures, with analysis of co-variation over time. Measures include: daily stressors, mood, coping style, personality, and health outcomes, as well as a number of neuroimmunological assays.

Progress: This project is still in the data collection phase. Over 70 subjects have now been recruited, baseline data are available on most of these and follow-up data collection is under way.

TITLE: Mood, Immunocompetence, and Illness

PI: Lester Luborsky
University of Pennsylvania
Dept. of Psychiatry Research Laboratories
(215) 662-2822

R&T PROJECT CODE: 442d004 CONTRACT NO: N0001487K0498

CURRENT END DATE: 28 FEB 1990

Technical Objective: (1) to explore the degree of inter-relationship of measures of mood, immune functioning and illness on a sample of cyclothymic subjects assessed longitudinally; and (2) to explore factors that mediate the inter-relationships among these measures, with special attention to endocrine and cognitive factors.

Approach: The research protocol involves within-subject longitudinal recurrent measurement of mood, immunocompetence, and illness, using each subject as his or her own control. Recurrent measurement will also be made of possible endocrine and cognitive mediating factors. Multivariate analyses will identify significant inter-relationships among these data.

Progress: This project is new in FY1988.

MANPOWER, PERSONNEL AND TRAINING RESEARCH AND DEVELOPMENT PROGRAM

TITLE: Self-improving instructional planners for intelligent tutoring systems

PI: Perry Thorndyke
FMC Corporation
Artificial Intelligence Laboratory
(408) 289-3112

R&T PROJECT CODE: 442c024 CONTRACT NO: N0001486C0487

CURRENT END DATE: 14 JUL 1988

Technical Objective: The aim is to develop a generalized architecture for a self-improving instructional planner that will dynamically develop plans, execute these plans, and improve its planning behavior based on a student's responses to tutoring. The generalized architecture for the planner will support the encoding of explicit theoretical descriptions of the teaching process, so that assumptions about the capabilities of each of the modules that support the planner can be analyzed, documented, and evaluated.

Approach: The method for developing the self-improving instructional planner is to generalize the work of O'Shea using the blackboard architecture BB1 developed by Hayes-Roth. Knowledge engineering techniques will be used to build a library of domain-deperdent and domain-independent knowledge that represents an explicit theory of teaching and an explicit theory of improving the instructor's performance. Experimental evaluations of the planner will be used to incrementally refine the generalized architecture. References : Hayes-Roth, B. (1985). A blackboard architecture for control. Artificial Intelligence 26, 251-321. O'Shea, T. (1982). A self-improving quadratic tutor. In Sleeman & Brown (Eds.), Intelligent tutoring systems. New York: Academic Press.

Progress: BB1, a general blackboard architecture, has been adapted to the requirements of an instructional planner, and a prototype instructional planning architecture, SIIP, has been implemented. An initial testbed application, operation and trouble-shooting of the 25mm weapon for the Bradley, has been explored. Instructional planning behavior was created by reverse engineering from the target instruction to the planning knowledge required to generate the instruction. A second testbed, a simple concept learning task that would allow rapid exploration of the adaptive capabilities of the system, is being explored.

Outside Funding: NTSC. AFHRL

TITLE: Qualitative Simulation and Intelligent Tutoring Aids

PI: T. Govindaraj
Georgia Tech Research Corporation
School of Industrial and Systems Engineering
(404) 894-3873

R&T PROJECT CODE: 4428004 CONTRACT NO: N0001487K0482

CURRENT END DATE: 31 MAY 1989

Technical Objective: Formalize a method for qualitative simulation of complex dynamic systems. Integrate a moderate-fidelity qualitative marine powerplant simulation with a blackboard-based instructional planning system to produce a prototype intelligent tutoring system and problem-solving aid for marine powerplant troubleshooting and maintenance. Test and refine the tutoring and simulation architecture.

Approach: Conduct fault diagnosis experiments using an existing moderate fidelity marine powerplant simulator. Enhance the simulator by incorporating operator inputs. Using the improved simulator, conduct further fault diagnosis and compensation experiments. Implement and experimentally evaluate an intelligent tutor-associate, using college, NROTC and Merchant Marine subjects at varying levels of expertise.

Progress: During the first few months of the project, the graduate students who will be working on it have mastered the necessary preliminary knowledge-- Interlisp-D programming, elements of steam propulsion, etc.

TITLE: Applying Artificial Intelligence to Causal Modelling

PI: Clark Glymour
Carnegie-Mellon University
Department of Philosophy
(412) 268-8571

R&T PROJECT CODE: 4428013 CONTRACT NO: N0001488K0194

CURRENT END DATE: 30 DEC 1988

Technical Objective: The objective is to develop a computer program that will use heuristic search techniques to automate the search for alternative causal models that might explain non-experimental data. It will accept as input either an initial causal model or partial prior knowledge about causal relationships. Plausible models will be automatically estimated and statistically tested. The program will be tested on the reanalysis of data on the determinants of enlistment, reenlistment, etc.

Approach: The researchers will conduct mathematical research into heuristic search algorithms for good causal models and will implement the results in a computer program with the characteristics described above. The program will interface to an existing, popular package for estimation and testing of structural equation modelling -- EQS or LISREL -- automating their use, rather than duplicating their functions.

Progress: This contract is new in FY1988.

TITLE: Conceptual Knowledge Foundations for Naval Medical Training

PI: Paul J. Feltovich
Southern Illinois University at Carbondale
Department of Medical Education
(217) 782-3318

R&T PROJECT CODE: 4428014 CONTRACT NO: N0001488K0286

CURRENT END DATE: 31 MAR 1989

Technical Objective: Biomedical concepts that are important in the training and job performance of submarine independent duty corpsmen will be identified and investigated in order to identify loci of conceptual difficulties and associated misconceptions. Guidelines will be suggested for improved training to overcome these difficulties.

Approach: A sample of students, instructors, and medical officers will be interviewed to identify important/difficult medical problem areas and related biomedical concepts. A detailed conceptual inventory questionnaire will be developed to probe understanding of those topics and will be administered to a larger sample of personnel, including active duty corpsmen. Four of the most important concepts will be the focus of in-depth investigations of trainee learning and understanding.

Progress: This contract is new in FY1988.

TITLE: Review of Research on the Design of Procedural Directions

PI: Thomas M. Duffy
Carnegie Mellon University
English Department
(412) 268-8701

R&T PROJECT CODE: 4428005 CONTRACT NO: N0001487K0253

CURRENT END DATE: 31 OCT 1987

Technical Objective: This project will produce a review and synthesis of recent research on the determinants of effectiveness in procedural directions.

Approach: A thorough bibliographic search will be conducted and an annotated bibliography prepared. Material will be organized according to the characteristics of the learner, task characteristics, characteristics of the material, and criteria for performance. Both a summary article and guidelines for the production of effective directions will be produced.

Progress: A database of articles and research reports on studies of procedural instructions, PROCEED, has been developed. An oral presentation of the framework for the review and of tentative conclusions was made to the MPT Committee. The final report is in preparation. (Note: The responsible person to contact about the content of this project is Dr. Barbara Hutson of VPI, 703-698-6061.)

TITLE: Training tactical operations: Knowledge compilation and team training approaches

PI: Kent E. Williams
University of Central Florida
Institute for Simulation and Training
(305) 281-5168

R&T PROJECT CODE: 4428012 CONTRACT NO: N0001487K0839

CURRENT END DATE: 13 SEP 1988

Technical Objective: The objective of this project is to produce an adaptive, artificially intelligent instructional system for training anti-submarine warfare tactics. Integration of team training techniques with this system will be explored also.

Approach: Consistent with John Anderson's theory of skill acquisition, the trainee's tactical skill will be represented by a production system model. A library of training problems will be developed and their presentation will be automatically controlled as appropriate to advance the current skill level of the trainee. Integration of previously developed strategies for training improved team performance in the embedded training situation will also be explored.

Progress: Detailed designs for the training system have been developed.

Outside Funding: NTSC

TITLE: Analysis of the Organization of Lexical Memory

PI: George A. Miller
Princeton University
Department of Psychology
(609) 452-5973

R&T PROJECT CODE: 442c026 CONTRACT NO: N0001486K0492

CURRENT END DATE: 28 FEB 1989

Technical Objective: The objective is to develop a novel kind of electronic lexical reference work, an augmented thesaurus, that is built upon a model of human lexical memory, in order to facilitate tasks in which the relationships of word meanings are important: design of technical and instructional documents, reading and use of such documents, and natural language computer interfaces.

Approach: A computer simulation of human lexical memory is being constructed. A master list of words is being used to simulate phonological access. Lexical concepts are represented as synonym sets. These lexical concepts are being extensively interconnected by networks of meaning relation- ships: opposition of meaning, part-whole relations, subordination relations, etc.

Progress: As of the end of 1986, 19,322 nouns had been organized into 4,011 synonym sets; 15,836 verbs had been organized into 3,208 synonym sets, and 5,100 adjectives into 943. Additional word entry is continuing with emphasis upon special military word senses. Emphasis has shifted to the entry of other semantic relationships. Explorations of the antonym relationships resulted in defining both an antonym relation between specific words and a more general relation of opposition of meaning. Work is progressing on hierarchical relations within the nouns, seeking classes of nouns that can specify acceptable arguments for verbs and adjectives. An interface to Wordnet has been developed.

Outside Funding: NPRDC (partial)

TITLE: The Improvement of Text Readability by Phrase-sensitive Formatting

PI: Thomas G. Bever
University of Rochester
Department of Psychology
(716) 275-3213

R&T PROJECT CODE: 4428016 CONTRACT NO: N0001488K0312

CURRENT END DATE: 31 MAY 1989

Technical Objective: The research objective is to expand the empirical base for an automated technique for formatting complex text using a phrase-separating algorithm which has already been developed and tested by the PI. Experiments will be conducted to examine the following variables (as well as others which may be suggested by these experiments): reading ability, text complexity, phrase size, space size, and retention interval. Results will be used to specify procedures for automatically formatting complex textual materials for improved readability and comprehensibility by readers of different levels of reading ability.

Approach: Carefully designed experiments with community college subjects, and possibly with Navy recruits or trainees, of different levels of reading ability will be conducted to examine the influences and interactions of several variables on reading speed, comprehension, and retention. The variables include reading ability, text complexity, phrase size, space size, and retention interval; other variables suggested by these experiments may also be studied. The phrase size and space size variables will be controlled by an algorithm for automatically formatting text which has been developed and tested by the PI.

Progress: This contract is new in FY1988.

TITLE: Artificial Intelligence Research in Navy Personnel Management

PI: Timothy B. Niblett
The Turing Institute
Industrial Studies
(041) 552-6400

R&T PROJECT CODE: 4428003 CONTRACT NO: N000148SJ1243

CURRENT END DATE: 31 AUG 1988

Technical Objective: The aim is to produce an expert system which is capable of acquiring information by generalization from expert-supplied examples, and which can provide overall system control functions for a large-scale personnel assignment system. The expert system will interface to a current system, based on operation research methods, which is being implemented and tested at the Navy Personnel Research and Development Center.

Approach: A logic programming framework will be used to design, test, and implement structured induction methods for the acquisition of expert rule-based knowledge about personnel assignment procedures. These methods of automated induction will be used to acquire a database of decision rules and procedures directly from the examination of expert behavior. This database will form the integral part of an intelligent control system for a larger personnel assignment/distribution system.

Progress: A study was conducted of the performance of ID3-like algorithms under noise. Bayesian analysis revealed two possible improvements in this class of algorithm. The improvements were implemented and successfully tested. A new algorithm for dealing with noisy data was developed, implemented, and tested. Initial work has been completed on a prototype system for generating explanations from local examination of a global optimization process.

TITLE: Optimal design in online item calibration

PI: Douglas H. Jones
Thatcher Jones Associates, Incorporated

(609) 895-0924

R&T PROJECT CODE: 4428007 CONTRACT NO: N0001487C0696

CURRENT END DATE: 30 JUN 1990

Technical Objective: This project is investigating alternatives to the random assignment of items to examinees in item-response-theory calibration studies. The ultimate aim is to develop procedures to adaptively gather data on new items. Issues under investigation include: (a) How to incorporate what is known about the unknown abilities in arriving at optimal designs. (b) The sorts of optimality criteria which should be used. (c) What to do when "optimal" examinees are not presently available? (d) How might optimal design solutions differ for preliminary item tryout and for fine tuning of the calibrations? (e) Which computational algorithms are most efficient in obtaining optimal designs? (f) How do we set stopping rules and otherwise deal with the fact that we are calibrating multiple items simultaneously? (g) How do we incorporate concerns about model uncertainty and protect against modest departures from the specified model? (h) How do we deal with item-person discordance.

Approach: Theoretical work will extend optimal design theory and develop methods for dealing with model uncertainty. Numerical work will compare the efficiency of numerical algorithms. Experimental work will investigate the issue of item-person discordance.

Progress: Recent progress has occurred in two important areas: First, investigators have formulated an objective function which incorporates uncertainty about examinee abilities (i.e., a design's control variables). Second, investigators have developed and implemented an efficient algorithm for maximizing that objective function subject to constraints on the difference between an examinee's ability and the difficulties of the items presented.

TITLE: Development and Evaluation of a Methodology for Composing Effective Naval Teams

PI: Robert Hogan
University of Tulsa
Department of Psychology
(918) 584-5992

R&T PROJECT CODE: 4423004 CONTRACT NO: N0001486K0644

CURRENT END DATE: 28 FEB 1990

Technical Objective: Team tasks require coordinating, transmitting and evaluating multiple task inputs, and are especially vulnerable to task degradation, particularly under the stressful operational conditions of the shipboard environment.The objective of this project is to develop and evaluate an innovative procedure for composing effective Navy teams in specific task environments.

Approach: Research will involve 4 phases: (1) developing a reliable nontechnical means for classifying effective performers; (2) developing a method for taxonomizing team tasks that will allow one to make predictions regarding effective team performance in differing task environments; (3) developing prototypical team tasks that reflect the major task categories; and (4) testing and refining this formulation through a series of composed group experiments, and defining its applicability to extant Navy teams.

Progress: Development of materials and procedures for the proposed experiments has proceeded well. Four experimental tasks (two "realistic" and two "social") and explicit performance criteria for those tasks have been created and a pool of research subjects with identified personality characteristics is set up. Nine experimental groups have so far been run, in each of which a three-person group carries out one realistic and one social task. Data collection procedures are working well, and data analysis is under way. A symposium describing the project was presented at the annual Southwestern Psychological Association conference.

Outside Funding: NTSC

TITLE: Team Evolution and Maturation

PI: Ben B. Morgan
Old Dominion University
Dept. of Psychology
(804) 440-4225

R&T PROJECT CODE: 4423005 CONTRACT NO: N0001486K0472

CURRENT END DATE: 15 JUL 1988

Technical Objective: Develop theory-driven procedures for measuring the performance of Navy teams at various steps in their life cycle and create novel training techniques for improving their effectiveness.

Approach: The research program includes the following steps: (1) refine the measurement of variables relevant to team maturation and development, (2) refine a working model of team evolution, (3) develop hypotheses regarding effective training interventions, (4) evaluate the relative efficacy of measurement and intervention tools using several different types of teams. Data will be collected through observations of Navy field operations and conduct of simulation exercises, interviews, and surveys.

Progress: Model building and measurement design have been completed. Data collection and analysis is complete for one Navy school (Naval Gun Fire School), and data collection is complete for a second school (ASW). Data collection has begun at a third site (Guided Missile School). Analytic work is under way to identify how the nature of variables controlling effectiveness of team performance varies over the stages of team evolution.

Outside Funding: NTSC

TITLE: Navy Training: Effectiveness of Team Training

PI: David W. Johnson
Regents of the University of Minnesota

(612) 624-7031

R&T PROJECT CODE: 4428002 CONTRACT NO: N0001487K0218

CURRENT END DATE: 14 MAY 1988

Technical Objective: There is strong basic science evidence that team learning, as compared with competitive and individualistic learning, promotes higher achievement, more analytical and higher-level reasoning, greater motivation to learn, and greater commitment to organizational goals. This series of exploratory development experiments is designed to provide the transition from basic science to Navy application.

Approach: Field-experimental methods will be used in the proposed studies. Within Navy training programs two instructional units will be used to determine the applicability of the previous research on team learning to Navy training. Insofar as possible trainees will be randomly assigned to conditions (stratifying for ability, ethnic membership, and sex), instructors will be rotated across conditions, and observational as well as self-report measures will be taken of the dependent variables.

Progress: Design of experiments and of data collection techniques is complete. A pilot study has been conducted and a TR is in preparation. A full study has been done using ROTC students at the PI's university. Two other studies have been completed at the Naval Technical Training Command Air Traffic Control School, and data analysis and report writing are under way. Early results strongly support the proposed merits of cooperative training.

TITLE: Forecasting Transformational Leadership

PI: Bernard M. Bass
State University of New York
School of Management
(607) 777-4028

R&T PROJECT CODE: 4428008 CONTRACT NO: N0001487K0434

CURRENT END DATE: 31 MAY 1989

Technical Objective: Establish the construct, concurrent and predictive validity of Bass's model of transformational leadership for determining future success of Naval academy graduates. The investigation will study the precursors of transformational leadership behavior, and the impact of such behavior on subordinate effort, satisfaction, effectiveness, and subsequent leader performance.

Approach: 300 Naval Academy graduates, the focal subjects, will describe themselves using the PI's Multifactor Leadership Questionnaire. Subordinates will also describe the focal subjects using the same instrument. Additional information will be obtained from the NPRDC Longitudinal Officer Data Base, Fitness Reports, and Naval Academy performance records. Data will be analyzed to test hypotheses drawn from the PI's theory.

Progress: The necessary administrative clearances and logistical arrangements have now been taken care of, and data collection is under way.

TITLE: Unconventional visual displays for flight training

PI: GAVEN LINTERN
University of Illinois
Institute of Aviation
(217) 333-3162

R&T PROJECT CODE: 4428009 CONTRACT NO: N0001487K0435

CURRENT END DATE: 20 JUN 1988

Technical Objective: To assess those aspects of simulator flight training that require high-fidelity visual displays and those that can be learned effectively with inexpensive low-fidelity displays.

Approach: Subjects will be trained on various flight tasks using visual displays of differing fidelity. They will then be transferred to a criterion situation to determine which flight tasks require high fidelity displays and which do not.

Progress: An experiment is in progress to investigate the effects of visual display fidelity on the acquisition and transfer characteristics of flight-related perceptual and motor skills.

TITLE: EAM: Scientific Consultant

PI: Wallace Sinaiko
Smithsonian Institution

(202) 357-1829

R&T PROJECT CODE: 4428032 CONTRACT NO: N0001480C0438

CURRENT END DATE: 28 FEB 1989

Technical Objective: This contract provides for short-term research, expert consultation, working groups, symposia and conferences, to supplement contract research programs in cognitive and neural sciences. It provides quick reaction responses to research problems associated with the human element in naval operations.

Approach: Continuing support to the programs of the ONR Manpower R&D Committee is provided in such areas as computerized adaptive testing, human resources accounting, attrition, and training.

Progress: The contractor has continued to provide necessary support for the bi-weekly meetings of the OCNR Manpower R&D Committee. During the past year he organized, conducted, and published the outcome of a major conference on reserve force manpower issues, and continued his chairmanship of an international panel of military manpower researchers which conducts collaborative research on such matters as the efficacy of innovative personnel selection and training technologies.

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